European Commission

Science for Energy

JRC thematic report

Joint Research Centre (JRC)

The European Commission's in-house science service

Joint Research Centre

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Foreword by Dominique Ristori

JRC Director-General

Clean, safe, secure and affordable energy is one of the greatest challenges facing Europe today. Sustainable and affordable energy is a prerequisite for a good quality of life and an essential ingredient for economic prosperity. In this respect, the European Union, as the rest of the world, faces a serious dilemma. On the one hand there is an increase in energy demand; on the other, Europe is confronted with the deterioration of the quality of the environment and the depletion of resources.

We know that energy requirements will grow by 50% by 2050 and at the same time we need to reduce CO_2 emissions. The increasing global demand, together with the need to tackle climate change, requires a major shift towards a low carbon economy. EU targets for 2020 are ambitious: cutting carbon emissions by 20%, reducing the energy consumption by 20% and increasing the use of renewable energy to 20% of total energy consumption. But this shift will only happen with the help of science and innovation, as the energy sector is becoming increasingly high-tech.

While the EU is making good progress towards meeting these targets, there is a need to reflect on a new 2030 framework for climate and energy policies. It must take into account the consequences of the economic crisis, by creating more demand for efficient and low carbon technologies and spurring research, development and innovation to ensure proper investment that will give us sustainable growth, affordable competitive energy prices and greater energy security.

The Joint Research Centre (JRC), the European Commission's in-house science service, provides scientific support to energy policy in a vast array of research areas, such as gas, oil, unconventional sources, nuclear energy, 'intelligent' systems for power transmission and distribution, biofuels and bioenergy, hydrogen, photovoltaic (PV) systems and energy efficiency.

For instance, the JRC manages SETIS, the Strategic Energy Technologies Information System, which regularly produces European and worldwide analyses of low carbon technologies identified as key for the future EU energy mix in the Strategic Energy Technology (SET) Plan. This information gives policy-makers the full picture and allows them to make informed choices.

Data show for example that the EU has a global market share of about 35% in the energy efficiency sector and existing buildings have a particularly high potential for energy savings in this area. As 90% of these buildings will still exist in 2050, renovating and upgrading them could in addition offer enormous savings while creating new jobs across Europe.

Regarding alternative fuels the JRC's research on biofuels addresses complex policy questions related to sustainability, greenhouse gas (GHG) emissions savings, direct and indirect effects of land-use change. Hydrogen is another alternative fuel which is being studied by JRC scientists looking in particular at aspects related to safety, performance, storage and end-use efficiency.

Renewable energy sources also play a key role in the transition towards a low carbon economy. They can reduce the EU's external energy dependency while promoting sustainability and competitiveness. In 2010 about 19.4% of the EU's gross final electricity consumption came from renewable energy sources. Hydropower contributed the largest share with 10.2%, followed by biomass with 3.5%, wind and solar power with 5% and 0.6% respectively. In Europe, solar photovoltaic electricity generation increased its cumulative installed capacity by more than 80% in 2010.

With its European Solar Test Installation (ESTI), the JRC assesses the performance of new and improved photovoltaic devices and performs pre-normative research and support to the development of international standards via the International Electrotechnical Commission (IEC) and the European Committee for Electrotechnical Standardisation (CENELEC). Its online photovoltaic geographical information system (PVGIS) provides maps and location-specific information on both the solar energy resources and the potential electricity output of PV technologies for Europe and Africa.

The JRC is also working on smart grids, the power infrastructure of the future, which is necessary for the distribution and transmission of electricity in a safe and efficient way. Since energy is not exempt from globalisation, developing international standards is crucial. Next to its involvement in international standardisation and regulatory bodies, the JRC cooperates with global energy partners such as the US Department of Energy, the International Renewable Energy Agency (IRENA) and the UN Intergovernmental Panel on Climate Change.

Through its research activities and expert knowledge the JRC also supports the European Atomic Energy Community (EURATOM), which pools EU competences, infrastructures and financial resources for a peaceful and safe use of nuclear energy. The JRC participated in the review of the safety of all EU nuclear power plants, for example, through a comprehensive and transparent risk assessment (nuclear 'stress tests').

The above are but a few examples of the many different areas where the JRC provides scientific support to energy policy, working together with an international network of experts. In doing so it contributes towards reaching the objective of cleaner, safer, more sustainable and affordable energy for Europe. I hope that this publication will help raise awareness of the need for solid science in our efforts to meet the global energy challenges and the JRC's role in this.

Introduction

This report aims to give a comprehensive overview of the work of the Joint Research Centre (JRC), the Commission's in-house science service, in relation to the global energy challenge. The description of the JRC's work in this area is divided into 7 chapters. For each chapter, the detailed policy context is cited, showing clearly how and where the JRC provides its scientific and technical support to energy-related policies. Furthermore, an ample list of publications for further reading is proposed as well as useful scientific tools such as maps, energy calculators, specialised information systems and databases.

1 Renewable energy

In 2020, at least 20% of the EU's overall energy consumption should come from renewable sources. The JRC collects, harmonises and disseminates EU-wide data on renewable energy resources. Solar energy is one key option and the JRC aims to accelerate photovoltaics (PV) market introduction by developing and harmonising international PV product standards. Bioenergy is another renewable energy source and the JRC's research in this field aims to provide balanced information to address the most relevant and delicate policy questions, spanning from analysis to sustainability testing.

2 Energy efficiency: doing more with less

A third of the total EU energy consumption is currently wasted through sheer inefficiency. Energy efficiency is a cost-effective solution which enhances energy security, reduces carbon emissions and saves money, and offers new business opportunities through the development of energy efficient technologies and services. The JRC's work in this field focuses on technology deployment and market uptake.

3 Security of energy supply: keeping Europe's lights on

Europe is highly dependent on energy imports, therefore EU-wide policies are needed to secure its energy supply. The JRC aims to provide a solid and comprehensive understanding of energy security in Europe, notably in relation to fossil fuels (gas and oil), and power systems.

4 Nuclear energy

To meet its need for secure, sustainable and economically viable energy supply, Europe needs a diversified energy mix with an increasing share of low carbon technologies. Nuclear power is virtually carbon-free and contributes about 30% to the current electricity generation in the EU. It is therefore expected to remain an important technology for electricity generation in the near future.

5 Ensuring a safe hydrogen economy

Hydrogen is an energy carrier with important environmental and energy security advantages. When renewable energy is used for its production, or when the CO_2 is captured, the hydrogen chain (from production to end-use) is completely emission-free. The JRC investigates the safety and storage aspects related to the deployment of hydrogen technologies and evaluates these in the best interest of Europe's citizens.

6 Assessing the role of energy technologies

Through its European Strategic Energy Technology Plan (SET-plan), the EU aims to meet its ambitious 2020 energy goals: cutting carbon emissions by 20%, reducing its energy consumption by 20% and increasing its use of renewable energy to 20% of its total energy consumption. To secure timely and reliable information on several energy technologies and thereby provide a solid base for decisions, the SET-Plan Information System (SETIS) was set up.

7 Energy Technology Innovation

Innovation in low carbon energy technologies is crucial for reaching the EU energy goals. The JRC assesses European capacities to innovate in energy technologies for instance through its role in SETIS. The JRC contributes with expertise to European and international standarisation organisations as standards are also a major enabler for technology innovation.

1 Renewable energy

1.1 Renewable energy assessment

Europe has committed itself to a very ambitious goal for 2020. By this date, energy coming from renewable sources has to represent at least 20% of the final energy consumption mix. Each Member State has developed its own strategy to reach this target and has submitted it to the European Commission as a renewable energy action plan. In order to achieve this goal, three main challenges need to be overcome for a proper exploitation of renewable energy: availability, exploitability and sustainability.

The JRC publishes an assessment of the National Renewable Energy Action Plans where the different Member States' renewable energy options are listed and compared with each other, in order to analyse how the burden sharing for the 2020 renewable energy targets is expected to look like in the coming years. A similar analysis is expected to be applied to the bi-annual progress reports foreseen by the Renewable Energy Directive.

The JRC's activities in this area provide scientific support to the following policy initiatives:

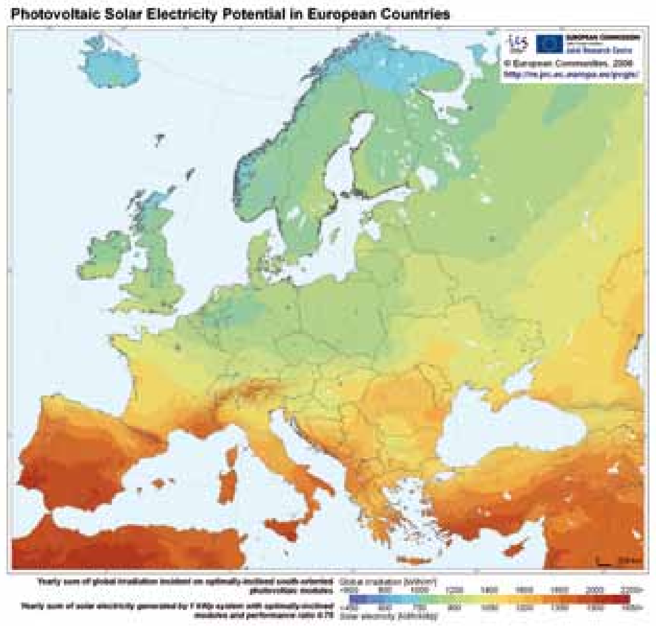
- Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources (Renewable energy directive - RED)
- Directive 2009/30/EC of 23 April amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions
- Commission Decision 2009/548/EC of 30 June 2009 establishing a template for National Renewable Energy Action Plans under Directive 2009/28/EC of the European Parliament and the Council
- Communication from the Commission – Offshore Wind Energy: Action needed to deliver on the Energy Policy Objectives for 2020 and beyond, COM(2008)768
- Communication from the Commission - From Cairo to Lisbon – The EU-Africa Strategic Partnership, SEC/2007/855
- Communication from the Commission – Towards a global partnership for sustainable development, COM(2002)82
- Communication from the Commission of 7 December 2005 – Biomass Action Plan, COM(2005)0628
- Report from the Commission on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling, COM(2010)11
- EU Energy Initiative for Poverty Eradication and Sustainable Development (EUEI)

The JRC assesses national and regional renewable energy options by analysing and comparing policy measures with respect to resources and technology. It also evaluates non-technical barriers to the rapid deployment of renewable energy technologies. To carry out these assessments and support EU policy making in this area, the JRC collects, harmonises and disseminates EU-wide data on the availability of renewable energy resources, with a special focus on maps showing their geographical location. This knowledge is used as a basis to study the extent to which the resources can be exploited. Particularly in the case of bioenergy, the overall sustainability of the production chain has to be carefully addressed. As a result, the JRC annually publishes a series of reports on resources, technology and implementation, such as the "photovoltaic status report" and the "renewable energy snapshots", which provide the latest available data in the EU on ongoing market developments at global level.

Availability of raw resources is the first step in assessing the potential of renewable energy exploitation. They are unevenly scattered in different areas of the world and have intrinsically lower energy content than fossil fuels. Their exploitation is therefore not feasible below a certain minimum density. For example, a minimum amount of wind or sun is needed for a profitable wind tower or photovoltaic panel. Thus, finding out the density of natural resources is a crucial aspect to design efficient energy strategies or possible scenarios. As an example, an assessment of how changes in wind and weather patterns will affect wind and solar energy production requires thorough knowledge of current and expected future energy production technologies.

Careful evaluation is also relevant for the legislative process in order to assess the final effect of incentives and constraints in terms of potential energy production and to avoid unsustainable exploitation of resources (e.g. collection of crop residues in areas with heavy soil erosion, excessive exploitation of wood resources). Biofuels, for instance, may not be produced on land in highly bio-diverse areas (primary forest, grasslands, protected areas) or on land converted from areas with high carbon stock (wetlands and continuously forested areas). In addition, the JRC collects data on transport infrastructure for energy and raw materials (e.g. natural gas grid for biogas, road network for biomass mobilisation, electricity grid, etc.) and data on the costs of the different steps of the supply chain. This information allows an improved monitoring of the national strategies.

In parallel, the JRC develops a similar activity for the African continent, which has clearly shown how the methodologies and tools developed in-house can be applied in other regions of the world, even in areas where there is limited availability of data.



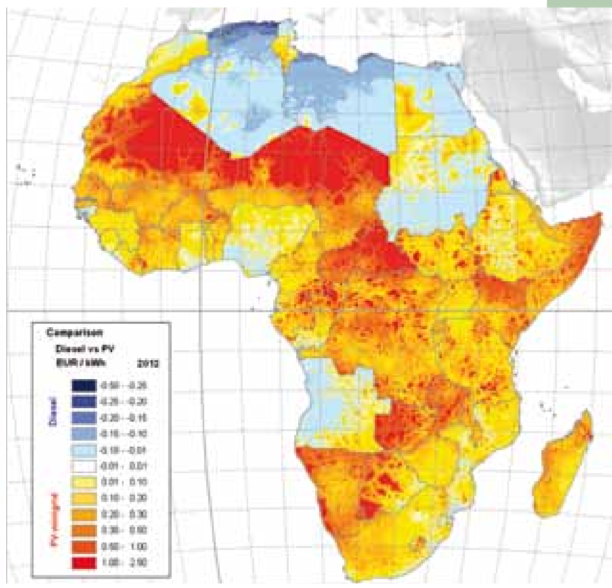
Estimates of solar electricity in Europe.

The JRC produces geographical databases, including maps, of available and sustainably exploitable resources to be used as a knowledge basis for potential assessment and scenario production. Examples of maps already produced include: solar radiation (for both Europe and Africa), agriculture residues density in Europe, potential energy from waste density in Africa and mini hydro area suitability for both Europe and Africa.

Work in Progress

The JRC is refining the geographical resolution of its energy maps and completing the evaluation of some complex resources (e.g. bioenergy) to be included in the maps portfolio. It is also assessing the effect of global threats (e.g. climate change) on renewable resources availability, especially in Africa, and it is strengthening its role as a reference point for information on renewable deployment in the EU and Africa.

In the near future the JRC will develop specific analysis deployment opportunities in the African region for renewables, also taking into account the key threats for the region, for instance, climate change. In addition, it will analyse the synergy among the different types of renewable energies in order to provide suggestions for optimal integrated use of resources.



The red/yellow areas show where PV is already more competitive than the diesel option in distributed electricity consumption. In countries where diesel is heavily subsidised, diesel tends to have the competitive edge.

1.2 Capturing the benefits of photovoltaics

Photovoltaics (PV) - the direct conversion of sunlight into electricity – exploit our most abundant renewable energy resource and are a key clean energy technology supporting Europe's fight against climate change. Rapid technological developments over the last 20 years coupled with a dramatic decrease in costs have opened the way for large-scale deployment. The production and installation of PV systems is now one of the world's fastest growing industries.

The JRC makes an annual independent assessment of these developments in its PV Status Report. Its European Solar Test Installation (ESTI) provides a unique reference facility for testing emerging PV technologies and developing the international standards needed to ensure market transparency.

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Commission Regulation (EU) No 1025/2012 on European Standardisation
- Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources
- Directive 2010/31/EU of 19 May 2010 on the energy performance of buildings (EPBD Directive)
- Communication from the Commission of 7 October 2009 - Investing in the Development of Low Carbon Technologies (SET-Plan), COM(2009)519
- Communication from the Commission of 6 January 2011 - A strategic vision for European standards: Moving forward to enhance and accelerate the sustainable growth of the European economy by 2020, COM(2011)311
- Communication from the Commission of 15 December 2011 - Energy Roadmap 2050, COM(2011)885

1.2.1 The European Solar Test Installation

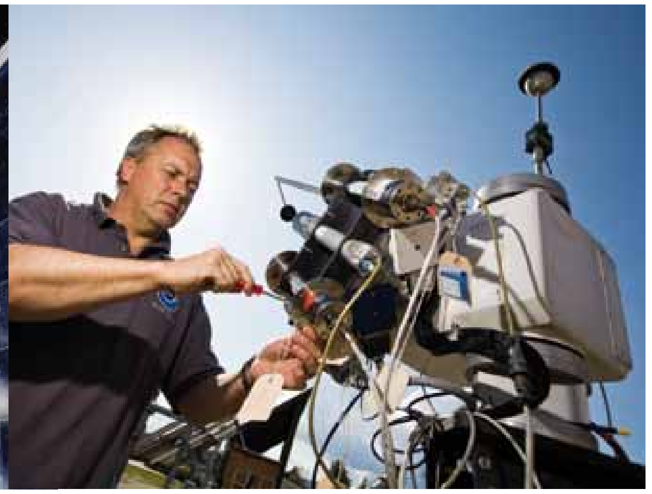
Established in the 1980s, ESTI is one of five laboratories worldwide for calibrating record breaking devices, as well as providing a service to industry to check the power performance and degradation resistance of new prototypes and products. The work directly addresses the EU's single market objectives and is an enabler for the implementation of EU policies to increase the share of renewable energy in electricity production and to improve the energy performance of buildings.

It is also significant that the growth in PV is linked with rapid technological development, not just scaling up. In fact, photovoltaics have enormous scope for improving energy conversion efficiency, as witnessed by the gap between the efficiency of current commercial products (10-20%) and the theoretical potential for efficiencies of over 60%. Independent reference laboratories such as ESTI are needed at European level to develop and improve traceable, accurate measurement techniques for new technologies, based on a full understanding of the technical issues. These feed directly into the ongoing improvement of the standards development process, which is critical to ensure the benefits of innovation can be quickly translated into commercial products in an open and transparent market.

ESTI is formally accredited under ISO 17025 for calibration of PV devices. The laboratory has experience with a large variety of PV technologies: mono- and multi-crystalline silicon, thin film (amorphous silicon, cadmium telluride, copper indium-(gallium)-di selenide) and multi-junction concentrator systems. The measurement capability covers cells of a few mm^2 up to modules of several m^2. The recent upgrading of equipment and laboratories puts this facility in a strong position to address future standardisation issues emerging from the rapid expansion of the PV market. These include, for example, power calibration for thin film, concentrated, and organic PV.

ESTI has already played a major role in developing the existing body of international standards on the PV field. ESTI has full participation rights (but not the right to vote) in the International Electrotechnical Commission and contributes extensively to its Technical Committee on photovoltaics. For the European Committee for Electrotechnical Standardisation (CENELEC), ESTI staff act as the Commission's non-voting technical representative to the committees dealing with norms for photovoltaics.

ESTI's new large-area steady state simulator opens a range of possibilities for studying the electrical performance of new module technologies with long response times.

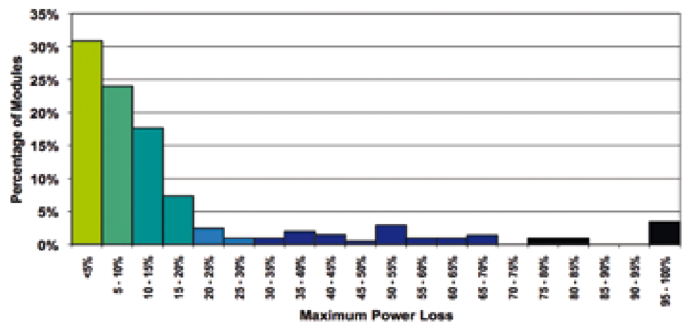


A JRC technician sets up the reference sensors for measuring solar radiation intensity. The final precision of the power values declared on calibration certificates provided by ESTI depends intimately on the accuracy of these instruments.

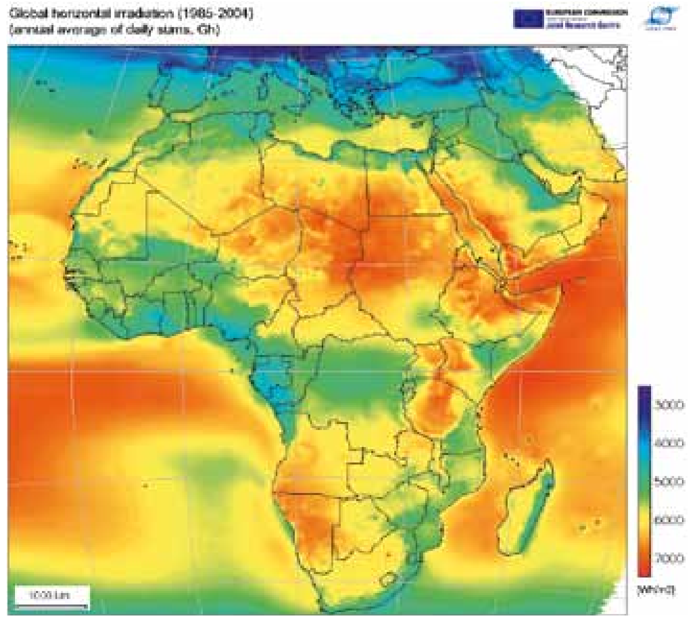
1.2.2 The competitiveness of PV as a source of electricity

ESTI's work also addresses two other factors that determine the competitiveness of PV as a source of electricity. The first is linked to solar resources: the JRC researchers use satellite images to produce solar radiation maps of Europe and Africa. Their accuracy is backed up by checks with ground-station data. In this respect, the JRC is actively working to improve the reliability of measurement techniques by providing technical support and reference instruments that allows the comparison of results from different European laboratories.

The second is related to the economic lifetime of PV devices. The JRC is at the forefront of studies involving accelerated ageing tests as well as long-term outdoor exposure under realistic operational conditions. The results are part of the body of data that underpins the extension of commercial module lifetime guarantees from 20 to 25 years. Further work on better understanding and quantifying the degradation processes aims to extend this lifespan to 30 years or more.



Results of over 20 years of outdoor exposure; power loss was lower than 10% for more than half of the 204 modules tested.



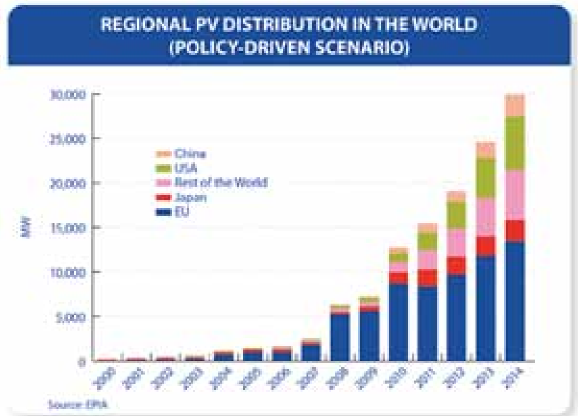
PV-GIS: yearly average global irradiation on optimally inclined modules in the Mediterranean and Africa [kWh/m^2].

Making reliable, independent information publicly available is a very effective tool to support the EU goals for renewable energy. The JRC's Photovoltaic Geographical Information System (PVGIS) produces solar radiation maps of Europe and Africa that show how much sunshine is available at a given location and how much electricity could be produced by a photovoltaic system. It is freely accessible online and helps investors, industry and individuals to make investment decisions and supports policymakers with data to design policies for PV deployment. This tool has become one of the most popular of its type in Europe, with more than 500,000 hits annually. It has also been used in techno-economic contexts, for instance to study the competitiveness of small off-grid PV systems in Africa compared to diesel generators.

Work in progress

Photovoltaics will play a major role in the EU's medium and long-term plans for low carbon energy systems. This continued growth coupled with increasing competitiveness will be characterised by rapid technological development, both in energy conversion devices and the overall systems to allow effective interaction with the energy infrastructure.

The JRC's independent role allows it to contribute effectively to the innovation process by developing performance standards for innovative concepts, collaborating with national research organisations and industry. Technologies of interest include very high efficiency multi-junction cells, luminescent concentrators, organic PV devices and integrated PV building products.



Regional PV distribution in the world.

1.3 Biofuels and bioenergy

The JRC's scientific activities on bioenergy and biofuels span from a vast array of analyses in different areas to the testing of biofuels sustainability. It includes topics such as greenhouse gas (GHG) emission savings, direct and indirect effects of land-use change, the overall availability of other primary energy sources or the most suitable and efficient production and transformation technologies.

The JRC's activities in this area provide scientific support to the following policy initiatives:

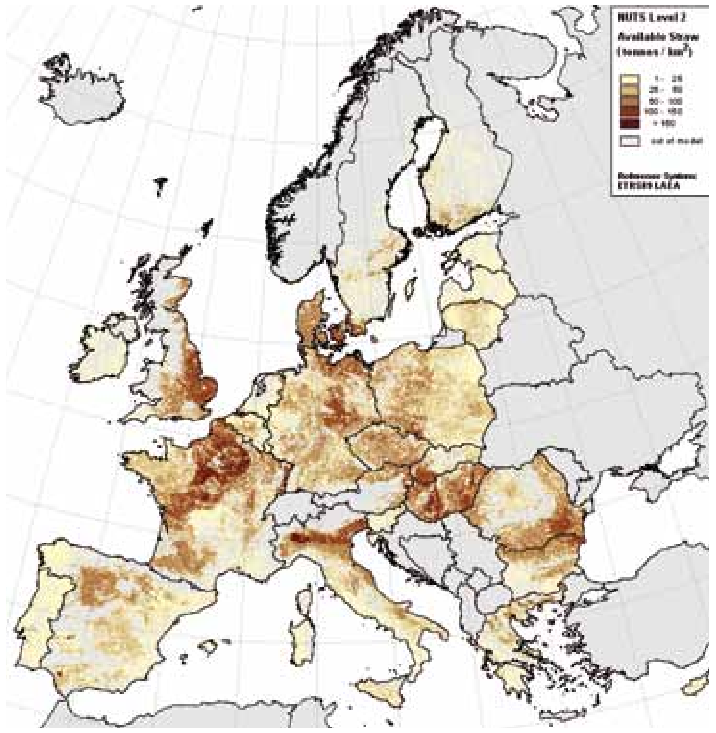
- Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources
- Directive 2009/30/EC of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC
- Directive 2009/33/EC of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles
- Communication from the Commission of 17 October 2012 – Proposal for a Directive amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources COM(2012)595
- Communication from the Commission of 28 April 2010 – A European strategy on clean and energy efficient vehicles, COM(2010)186
- White Paper on the Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, COM(2011)144

Bioenergy is seen as an important contributor to meeting the EU aim of increasing its use of renewable energy to 20% of total EU consumption by 2020. According to the Renewable Energy Directive, 10% of the transport sector's final energy consumption in 2020 should also come from renewable energy sources.

While some biofuels can be mixed with conventional fuels and used in existing engines without major modifications, blends with a higher concentration of biofuels and pure biofuels require dedicated engines. Adding biofuels to conventional fuels generally results in significant modifications of fuel properties, which in turn can have a positive or negative impact on the emissions, since fuel systems, engines and after-treatment devices are designed and optimised for conventional fuels.
The JRC investigates biofuels as well as the energy efficiency of conventional and advanced powertrains and vehicles at the Vehicle Emissions Laboratory (VELA). VELA comprises two chemical and physical analysis labs, and seven testing facilities for emissions testing on a variety of vehicles, from mopeds to lorries. Research findings at these facilities have provided key scientific support for the development and revision of EU legislation, as well as for the development and assessment of new measurement techniques and procedures.

The EU legal framework also sets environmental sustainability criteria for both biofuels and bio-liquids, including a requirement of a 35% reduction in greenhouse gas emissions with respect to the fossil fuel in use. Specific land-use categories such as primary forest, grassland with high biodiversity, wetlands and peatlands for the production of biofuels and bioliquids in use in the EU are also excluded by the EU directives.

Bioenergy is an important contributor to meeting the EU's aim of using 20% renewable energy by 2020.



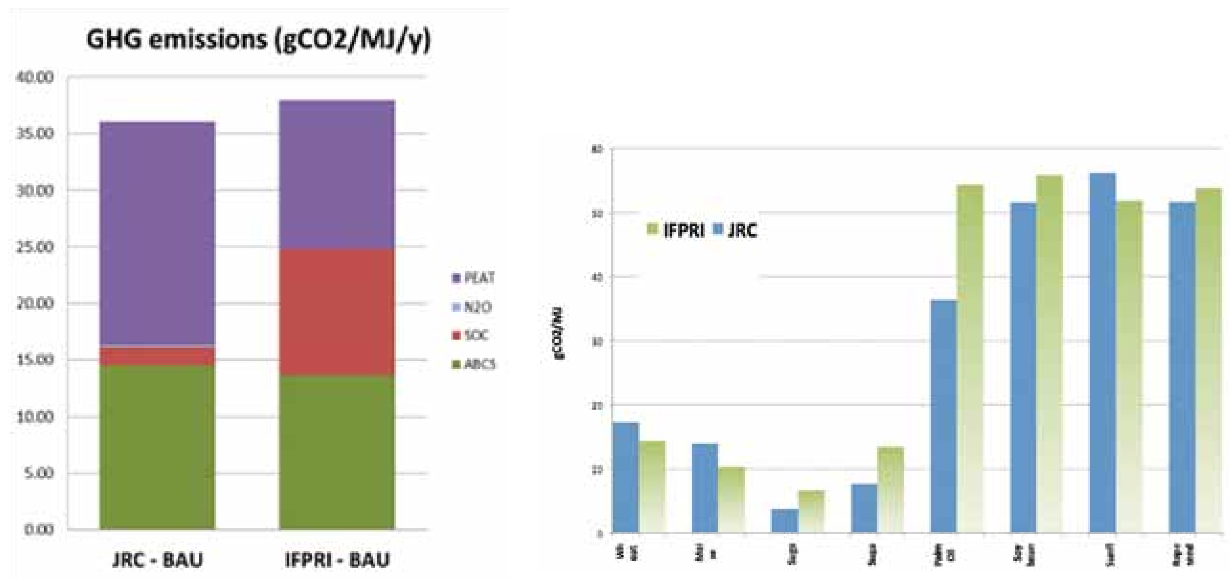
Tonnes of straw and crop residues per square kilometre potentially available for energy use in EU-27.

1.3.1 Calculating emissions from land-use change

Increased EU demand for biofuels could have a significant impact on land use in EU countries and beyond. These land-use changes can lead to changes in carbon stocks in soils and biomass, and subsequently to changes in GHG emissions. If biofuel crops are grown on previously uncultivated land, direct land use change will be the result. However, in general, crops for biofuels are grown on existing arable land already used for food production. Since 2008, when the JRC first warned about the potential increase of greenhouse gas emissions from indirect land use changes (ILUC), the Commission has carried out a number of studies to assess these effects. In 2012, the Commission put forward a policy proposal on how to take ILUC effects into account in the Renewable Energy and Fuel Quality directives.

The Commission has also proposed that the use of food-based biofuels to meet the 10% renewable energy target of the Renewable Energy Directive shall be limited to 5% in order to limit global land conversion for biofuel production and raise the climate benefits of this kind of fuel.

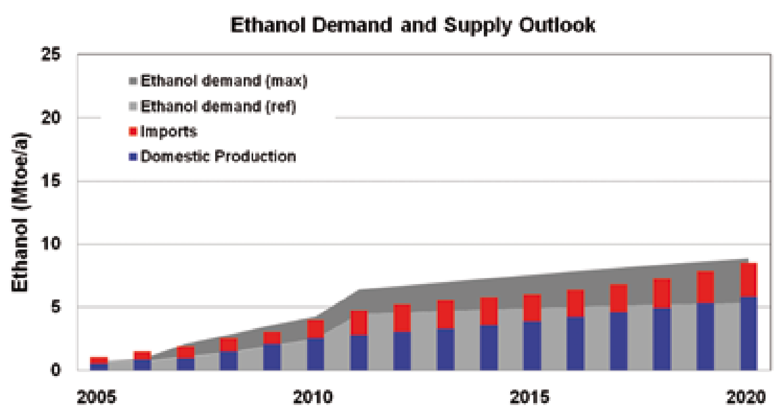
As part of the impact assessment, the JRC compared assumptions and results from several models used to estimate ILUC worldwide. Furthermore, the JRC has developed a new methodology to estimate greenhouse gas emissions resulting from ILUC. These emissions arise from loss of standing biomass, loss by oxidation of organic matter in the soil in the years after conversion, and loss of nitrogen in the organic matter released as N_2O.
All the assessments show clearly that, in general, ethanol crops have lower ILUC impacts than oilseed/biodiesel crops.



Comparison of total (left side) and 'crop-specific' (right side) GHG emissions from LUC due to biofuels increased demand between JRC and IFPRI (International Food and Policy Research Institute) estimates for 2020.

1.3.2 Biofuels life-cycle analysis

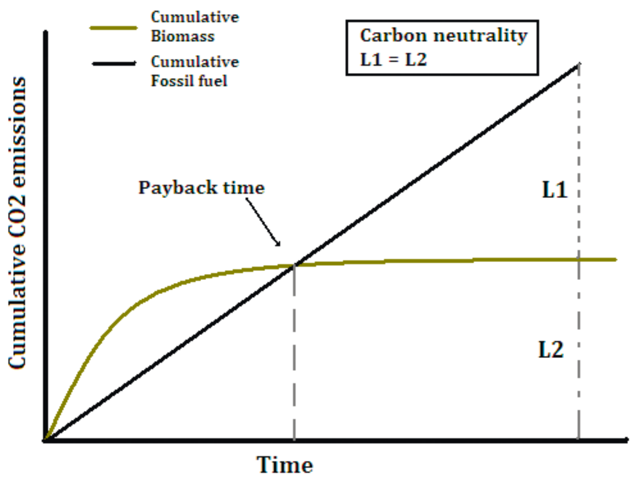
The JRC produces and maintains input data used to calculate default direct emissions during the whole life cycle (from raw material extraction/ growing through processing, manufacturing, distribution, and use) of biofuels, biomass and biogas, which among other things are used in the context of the Renewable Energy Directive. The JRC database is also used in the framework of the research collaboration with the European research associations of the automobile and oil refining industries to produce and update Well-to-Wheels (WtW) reports. These reports are not limited to biofuels but include all conventional and alternative fuel pathways relevant to the European road transport situation. Energy efficiency and emissions in the WtW analysis are calculated using a different methodology compared to the mandates of EU legislation. The JEC (JRC, EUCAR, CONCAWE) is also active in analysing alternative scenarios to achieve the 10% EU target by 2020 for renewable energy content in transport.
The JRC also collaborates with biofuels producers and associations in and outside the EU to improve the accuracy of input data used to calculate life cycle default GHG emissions. All publications, including raw data used for analyses, are freely available online.



Demand and supply of ethanol.

1.3.3 Carbon accounting of forest bioenergy

In collaboration with forestry experts, the JRC is working on clarifying the phenomena underpinning the methodologies and results in forest carbon accounting. In the current European climate change policy framework, forest biomass used for energy and transport is considered as an inherently carbon neutral source – in other words, it is assumed that the CO_2 that is liberated when the biomass is burned will be used up when the forest vegetation grows back. But, in the case of roundwood (not yet chopped or sawn), given the long rotation time of the forests and the relative short time period within which greenhouse gas emissions have to be reduced according to climate change policy objectives (e.g. until 2020), this is not a valid assumption. Due to the long rotation times of these forests, not all of the CO_2 emitted during biomass combustion is reabsorbed in such a short time, which leads to a temporary increase in atmospheric CO_2. In addition, the combustion of biomass releases more CO_2 than fossil fuels per unit of energy produced, because of the lower energy density and lower conversion efficiencies. All together, these phenomena create an emission of biogenic-CO_2 from forest bioenergy which is, in most cases, higher than the emissions from a reference fossil system in the short term. This is the so called “carbon debt”. The forest re-growth combined with the continuous substitution of fossil fuels will, in time, repay the “debt”.
Via a detailed analysis and review of the currently available literature, this work aims to clarify the dynamics of the carbon debt created by burning forest biomass, and at compiling the methodologies and results reported so far. The results will serve as a basis for the JRC to define methodologies for a proper assessment of the carbon impacts of using biomass in the bioenergy sector.



Visual description of carbon neutrality and payback time.

The JRC’s activities in the field of biofuels and bioenergy are pivotal in defining thresholds and reference values for mandatory EU legal requirements. Also the Well-to-Wheels results issued from the JEC research collaboration have established themselves as the European scientific reference.

In addition, the BIOMAP provides unique information on projects funded by the EU and other sources on biofuel technologies and feedstocks, including legislation, quality specifications and the key stakeholders.

Work in progress

The JRC is continuously carrying out comprehensive updates of default greenhouse gas (GHG) savings for additional biofuel, bioliquid and biomass pathways, including next generation biofuels, and an update of existing pathways.

The JRC will also perform an assessment of carbon debt and net carbon emissions savings related to payback time of release and recovery of CO_2 emissions from sustainable forestry. In addition, it will work further in order to reduce the uncertainties and to improve the understanding of indirect land use change (ILUC) impacts associated with biofuels production. It will quantify the impact of biofuels and bioenergy production on biodiversity both in the EU and third countries. The JRC will moreover revise and update scenarios for achieving the mandatory 5% renewable energy target by 2020 in all transport modes, and revise, update and expand energy/fuel and powertrain pathways relevant to the European road fleet.

2 Energy efficiency: doing more with less

Currently one third of the energy consumed in the EU is simply wasted, due to sheer inefficiency. Energy efficiency is a cost-effective solution to enhancing security of supply, reducing carbon emissions and saving money. It also creates new business opportunities through the development of energy efficient technologies and services.

2.1 Energy efficiency – a pillar of the EU energy policy

As energy efficiency is a central pillar of the EU's goal to reduce energy consumption by 20% in 2020, the JRC's work focuses on technology deployment and market uptake, defining criteria to assess policy measures that can contribute to the implementation of energy efficient technologies. With the data, analyses and indicators on implemented policies and measures, the JRC supports EU decision makers in taking informed decisions. Most advice concerns energy service companies, the energy performance of buildings and the efficiency of products as regulated by the Ecodesign Directives. Ecodesign implies taking into account all the environmental impacts of a product right from the earliest stage of design. The Ecodesign Directives provide a coherent and integrated framework which allows setting mandatory ecodesign requirements for some products.

The JRC also provides scientific and technical support to cities in the EU Member States and Eastern European, Central Asian and Southern Mediterranean countries for the development of local sustainable energy plans (SEAPs), assesses these SEAPs and monitors their implementation.

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Commission Delegated Regulation No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements
- EC Regulation No 106/2008 of 15 January 2008 on a Community energy-efficiency labelling programme for office equipment
- Directive 2010/31/EU of 19 May 2010 on the energy performance of buildings (EPBD Directive)
- Directive 2010/30/EU of 19 May 2010 on the indication by labelling and standard product information on the consumption of energy and other resources by energy-related products
- Directive 2009/125/EC of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (Ecodesign Directive)
- Directive 2006/32/EC of 5 April 2006 on energy end-use efficiency and energy services (Energy Service Directive)
- Directive 2012/27/EU of 25 October 2012 on energy efficiency and repealing Directives 2004/8/EC and 2006/32/EC (Proposed Energy Efficiency Directive)
- Communication from the Commission of 15 March 1999 on Policy Instruments to Reduce Stand-by Losses of Consumer Electronic Equipment, COM(1999)120
- Communication from the Commission of 8 March 2011 on the Energy Efficiency Plan 2011, COM(2011)109

2.2 Energy efficiency in buildings

The JRC manages the GreenLight and GreenBuilding programmes, which are voluntary initiatives that aim to encourage public and private actors to intensify their energy-saving efforts.

The GreenLight programme encourages public and private organisations to install energy-efficient lighting technologies. The JRC provides support in the form of wide public recognition and guidance to implement the most advanced energy efficiency technologies. The programme now counts more than 700 participants, who altogether save more than 300 GWh/year thanks to their changes in lighting.

The GreenBuilding programme aims to raise awareness and trigger additional investments in energy efficiency and renewable energy among owners in new and refurbished non-residential buildings. With more than 380 participants and 650 buildings, the programme saves more than 514 GWh per year through better insulation, more efficient heating, cooling or lighting devices, control systems and energy management.

To calculate the reduction of energy consumption in buildings, a common calculation methodology is needed to include all the aspects determining the energy consumption of the building which combines energy savings (e.g. insulation), increased energy efficiency in heating and cooling, use of renewable energy resources and the behaviour of the occupant. The JRC is collaborating with the European Committee for Standardisation (CEN) to develop an overall energy consumption calculation methodology.

Several participants in the GreenLight, GreenBuilding and the Code of Conduct initiatives.

2.3 Ecodesign

All products have an impact on the environment during their life cycle, from production to waste. Ecodesign implies taking into account all the environmental impacts of a product, right from the earliest stage of design. The EU introduced the Ecodesign Directive with conditions and criteria to help manufacturers develop more environmentally friendly electrical products. The first 13 resulting ecodesign measures are expected to save around 366 TWh per year by 2020, the equivalent of more than 12% of the electricity consumption of the EU in 2009.

Estimated annual savings through Ecodesign measures
The first 13 measures (more are planned) equal annual savings by 2020 equivalent to more than 12% of the electricity consumption of the EU in 2009.

Ecodesign Measure	Adoption	Estimated annual savings by 2020
Standby	December 2008	35 TWh
Simple set top boxes	February 2009	6 TWh
Street & Office Lighting	March 2009	38 TWh
Domestic Lighting	March 2009	39 TWh
External power supplies	April 2009	9 TWh
Electric motors	July 2009	135 TWh
Circulators	July 2009	23TWh
Domestic refrigerators	July 2009	4 TWh
Televisions	July 2009	28 TWh
Domestic dishwashers	November 2010	2 TWh
Domestic washing machines	November 2010	1.5 TWh
Fans	March 2011	34 TWh
Air conditioners and comfort fans	March 2012	11 TWh
Total		**366 TWh**

For up-to-date information on all Ecodesign measures, please refer to the website: http://ec.europa.eu/enterprise/ecodesign

The Ecodesign Directive is meant to be used together with other policy tools and allows the Commission to regulate the minimum performance of products. As a consequence it "pushes" the market away from the worst performing products and "pulls" it towards more efficient ones.

2.4 EU Codes of Conduct for ICT

Together with industry, the JRC develops energy-saving codes of conduct for Information and Communication Technologies (ICT). They provide a platform bringing European stakeholders together to discuss and agree voluntary actions which will improve energy efficiency. The codes' key aim is to inform and stimulate the ICT industry to reduce energy consumption in a cost-effective manner without hampering the critical function of the facility or the equipment.
Energy consumption in this domain is rapidly increasing, and due to the fast penetration of new and digital technologies, it is likely to increase even more. Currently, there are five codes of conduct covering external power supplies, digital TV services, Uninterrupted Power Supplies (UPS), broadband equipment and data centres.

To name an example, the Code of Conduct for Data Centres gathers a series of best practice recommendations on design, purchase and operation in areas like software, IT architecture and IT infrastructure. For instance, on the efficient management of environmental conditions, a recommendation is to provide cooling exactly where it is needed on the server central processing units (CPUs) and to avoid overcooling.

Every two years, the JRC publishes a report on the status of the energy consumption in the EU. The most recent also covers energy efficiency in the EU-27 residential and tertiary sectors, contributing to the monitoring of the energy efficiency progress made and providing estimates of the savings potential for the future.

Work in progress

The JRC will collect and publish updated information, data, and analysis on energy efficiency technologies and policies. It will also prepare the scientific and technical support for the Regulations for end-use equipment such as lighting, consumer electronics, motor systems and ICT. The JRC will analyse the technical and non-technical barriers to energy efficiency investments and the new developments in the energy services market, including ESCOs (energy service companies) and it will furthermore help prepare the ground for the next revision of the "energy efficiency in buildings" Directive by using data and experiences from the European GreenBuilding Programme, thereby promoting very low or "zero" energy buildings (NZEBs).

3 Security of energy supply: keeping Europe's lights on

Europe is highly dependent on energy imports; more than 50% of its energy consumption comes from external sources. Scientific and technological research can help secure Europe's energy supply by supporting the most convenient policy decisions. As the in-house science service of the European Commission, the JRC aims to provide a solid and comprehensive understanding of energy security in support of EU policy, notably through research on fossil fuels (mainly gas and oil) and power systems.

The JRC's activities in this area provide scientific support to the following policy initiatives:

For gas and oil
- Regulation No 994/2010 of 20 October 2010 concerning measures to safeguard security of gas supply and repealing Council Directive 2004/67/EC
- Proposal for a Regulation of 27 October 2011 on safety of offshore oil and gas prospection, exploration and production activities, COM(2011)688
- Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection
- Communication from the Commission of 15 December 2011 - Energy Roadmap 2050, COM(2011)885
- Impact Assessment accompanying the document 'Proposal for the Regulation of the European Parliament and of the Council on safety of oil and gas prospection, exploration and production activities', COM(2011)688

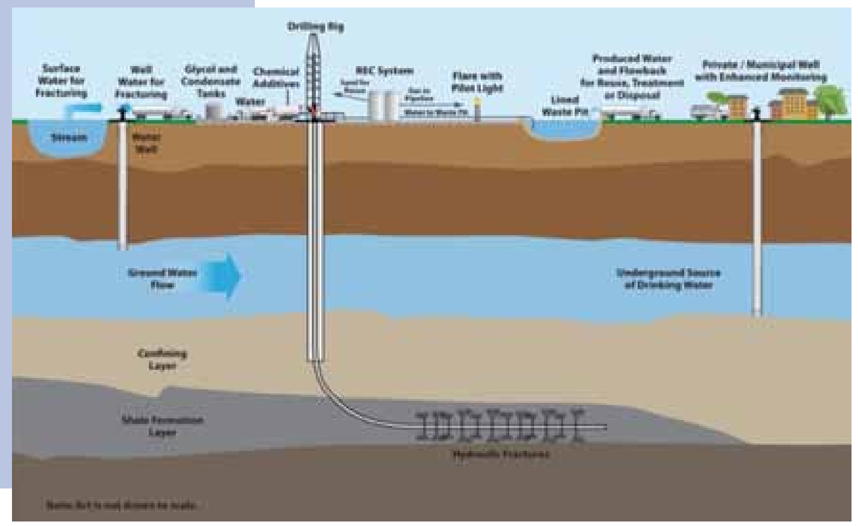
For power systems
- Directive 2003/54/EC of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC
- Communication from the Commission of 12 April 2011 - Smart Grids: from innovation to deployment, COM (2011)202
- Communication from the Commission of 3 March 2010 - Europe 2020: A strategy for smart, sustainable and inclusive growth, COM(2010)2020

3.1 Gas and oil

Fossil fuels are by far the largest sources of energy in Europe. Oil, gas and coal represented just over 75% of gross inland consumption in 2010. While governmental support will ensure that alternative energy sources such as renewables increasingly contribute to the total energy supply, fossil fuels are widely projected to dominate the European energy mix until at least 2030.

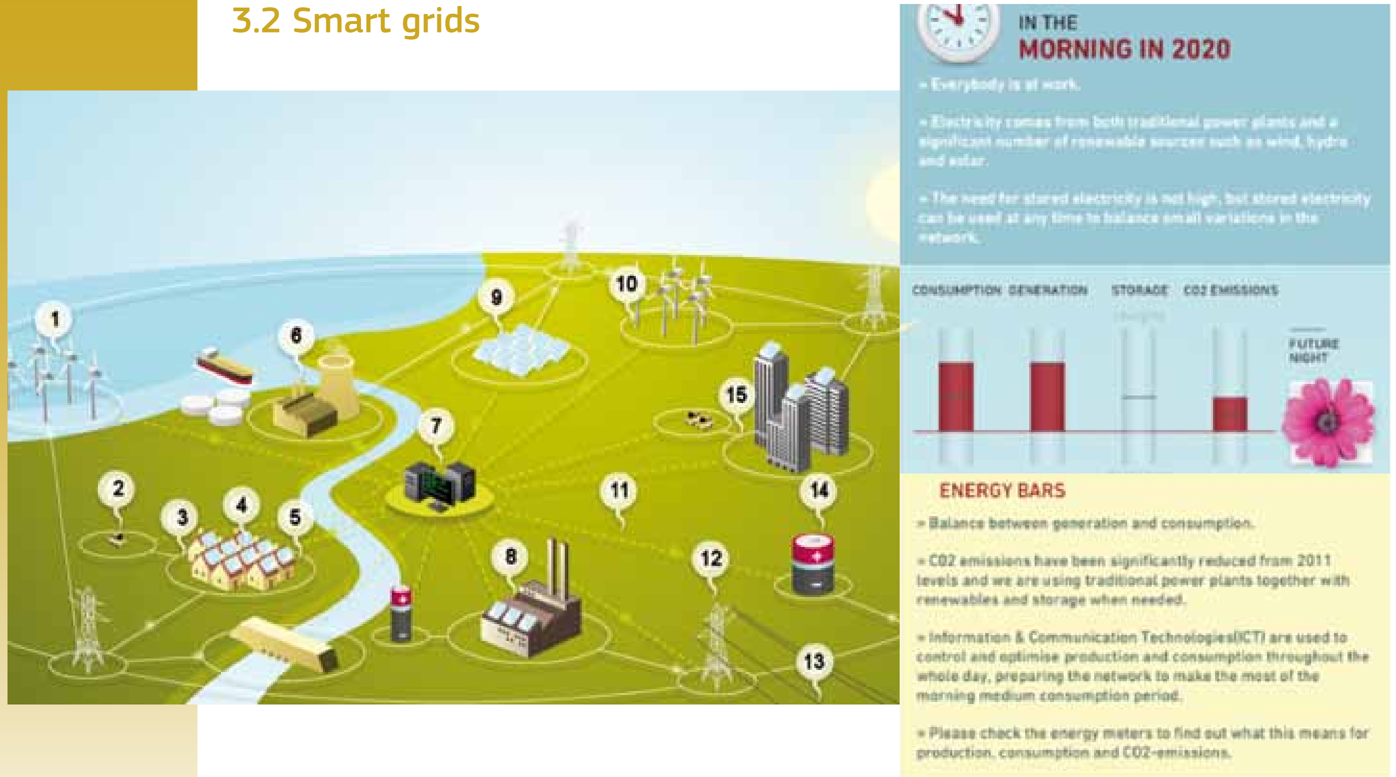
In relation to gas, the JRC develops and implements models to study the EU gas transmission system and provides techno-economic analysis of energy security, enabling the identification of potential crises and flaws affecting the gas infrastructure and markets. It also assists Member States by providing guidance concerning the security of gas supply and reviewing risk assessments of Member States' gas systems. These models and methods enable the identification of potential crises and flaws in the gas infrastructure and markets. The JRC also supports EU countries by reviewing preventive action plans designed to improve gas systems and emergency plans designed to cope with infrastructure and market disruptions.

In addition, the JRC analyses the impact of unconventional gas and oil sources (with a focus on shale gas) on the EU's energy security. JRC experts also perform research on offshore gas and oil resources, focusing on the safety of deep water explorations and exploitations.



Hydraulic fracturing.

3.2 Smart grids



Smart electricity grids are electricity networks that can intelligently integrate the behaviour and actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.

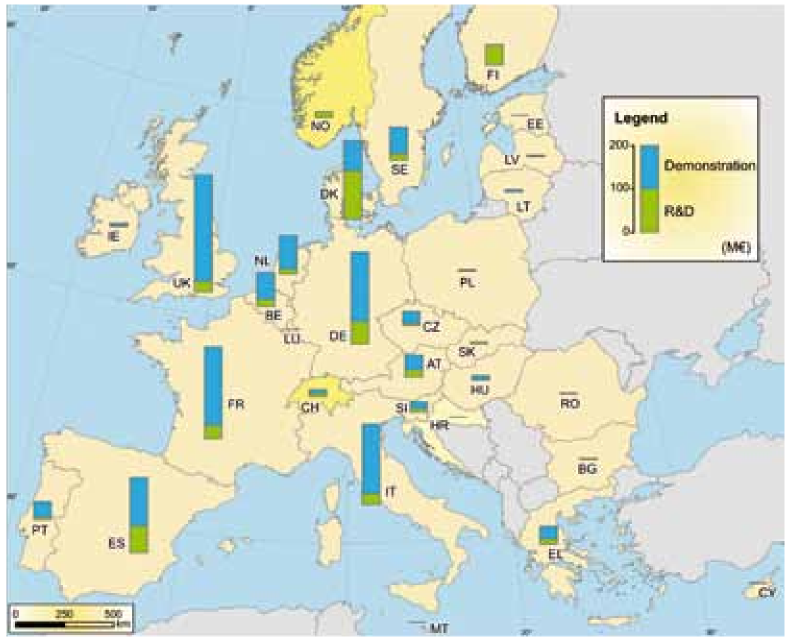
Meeting the EU's climate change and energy objectives for 2020 and beyond requires a major transformation of our electricity infrastructure, which needs to be upgraded and reshaped to foster sustainability, increase energy efficiency and enhance grid security. As the EU power grid is one of the largest and most complex systems in the world, this is a major technological, financial, societal and regulatory challenge.

A smart grid is an electricity network that is set up to continuously process and respond to the behaviour and actions of producers and consumers in order to efficiently deliver electricity supplies. Many countries in Europe and worldwide are now promoting concepts for smarter grids and 'super grids' (wide area transmission networks to trade high volumes of electricity across great distances) in order to integrate new actors and technologies in the power system, such as renewable energies, storage devices and electric vehicles.

The JRC monitors the transition of the EU power network towards smart grids by developing models and making analyses. An example is a power grid model that started with data from the European Transmission System Operators and was complemented by other datasets from the European power system. This model now includes more than 10,000 elements (nodes and lines) of Europe's transmission grid and can be used to run static and dynamic analyses of the European transmission network. The JRC also performs cost-benefit analyses of smart grid projects, and has become an international reference point for information on smart grid pilot and demonstration projects. It monitors the developments, maintains a smart grid simulation centre, analyses the technological, social and economic factors involved and disseminates information on smarter electricity systems. In addition, the JRC closely collaborates with the US Department of Energy on e-mobility and smart grids. Two smart grid Interoperability Centres are being set up, one in the US and one at the JRC facilities in Europe.

In the last few years, smart grid projects have been growing in number, size and scope throughout Europe. In 2011 the JRC launched the first comprehensive inventory of smart grid projects in Europe, which includes over 200 smart grid projects located across Europe. Project results provide an encouraging indication of how smart grids can help integrate more renewable energy, accommodate electric vehicles, give more control to consumers over their energy consumption, avoid blackouts and restore power quickly when outages do occur.

The JRC has also defined a comprehensive approach for cost-benefit analyses of smart grid projects. The smart grid project InovGrid was used as a case study to fine-tune and illustrate the proposed methodology and perform a cost-benefit analysis on a real project. This work draws on a methodology proposed by EPRI (Electric Power Research Institute) and on the collaboration between the JRC and the US Department of Energy.



Geographical distribution of RD&D investments in smart energy systems.

The JRC has carried out a study on the impacts in the EU energy market of unconventional fossil fuels, in particular shale gas. The study shows that following the extraction of unconventional gas in the US, greater supplies of liquefied natural gas (LNG) have become available at global level, indirectly influencing EU gas prices. It also suggests that under a best case scenario, taking into account environmental considerations, future shale gas production in Europe could help the EU maintain its dependency on energy imports at around 60% of its total energy needs. But the report also reveals the sometimes considerable uncertainty about recoverable volumes, technological developments, public acceptance and access to land and markets.

Work in progress

The JRC is working on the development of a smart grid laboratory to investigate the characteristics and assess the performance of components, systems and technologies and their interactions. It is also setting up a laboratory equipped with an advanced power system real-time simulator, which can be used, among other things, for alternating current power grid simulation, global control development and protection system testing.

The JRC is furthermore developing a conceptual framework to address the issue of energy security in the EU in a fully integrated manner. This means including elements from the very access to the primary energy sources to the reliability, vulnerability and resilience of the networks used to bring the energy to the EU, also taking into account access to energy markets and new elements in the energy market, such as shale gas. It is also working on enhanced policy support for the safety of offshore oil and gas activities. This includes performing a baseline study and review of offshore industry and regulatory best practices, analysing offshore major hazard indicators and developing a common data reporting format and a knowledge centre on offshore risk management. In addition, the JRC holds the Technical Secretariat of the EU Offshore Authorities Group (EUOAG).

4 Nuclear energy

The need for a secure, sustainable and economically viable supply of energy in Europe calls for the development of a diversified energy mix with an increasing share of low carbon technologies. Nuclear power contributes about 30% to the current electricity generation. A significant number of EU Member States rely on nuclear power in their national energy mix, as part of a long-term strategic energy infrastructure.

Nuclear energy can indeed contribute to a diversified energy mix through a combination of technical measures: maximising the service life of existing nuclear power plants (NPPs), building new evolutionary light water reactors (LWRs) of the third generation (Gen III), and ultimately developing, demonstrating and deploying a new generation (Gen IV) with further improved safety, reliability, sustainability, economic competitiveness, proliferation resistance and physical protection. With a time horizon up to 2050, the Sustainable Nuclear Energy Technology Platform (SNETP) unites more than one hundred players in Europe to identify the technological needs associated with those measures, while the European Nuclear Energy Forum (ENEF) gathers governments of the EU Member States, European institutions, industries and the civil society to provide a platform for discussion on transparency issues and the opportunities and risks of nuclear energy.
Safety of nuclear installations in Europe and beyond is of paramount importance. Through its research activities and expert knowledge the JRC supports the European Atomic Energy Community (EURATOM), which pools the competences, infrastructures and financial support for the peaceful and safe use of nuclear energy.

4.1 Safe Operation of Nuclear Power Plants

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Treaty establishing the European Atomic Energy Community (Euratom Treaty)
- Directive 2009/71/EURATOM of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations
- Directive 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste
- Communication from the Commission of 4 October 2012 on the comprehensive risk and safety assessments ("stress tests") of nuclear power plants in the European Union and related activities, COM(2012)571
- Council Regulation (Euratom) no 300/2007 of 19 February 2007 establishing an Instrument for Nuclear Safety Cooperation
- Council Regulation (EC) no 1085/2006 of 17 July 2006 establishing an Instrument for Pre-Accession Assistance
- Communication from the Commission of 16 September 2011 - 1st situation report on education and training in the nuclear energy field in the European Union, COM(2011)563

Feedback from the 437 nuclear reactors in operation worldwide is a priceless source of information to continuously improve nuclear safety. In order to maintain an effective experience feedback mechanism, a wide range of information is accessed, and this requires resources and expertise to process it. This is why a European initiative, called the European Clearinghouse on Nuclear Power Plants Operational Experience Feedback ("EU Clearinghouse") has been set up in support of EU nuclear safety authorities, EU technical support organisations, international organisations and the broader nuclear community. Its purpose is to enhance nuclear safety through the lessons learned from operational experience.

The experience gained in the activities of the EU Clearinghouse has been key to the effective participation of the JRC in the safety review of all EU nuclear power plants through a comprehensive and transparent risk assessment (i.e. the nuclear "stress tests" organised by the European Commission in the aftermath of the Fukushima accident). This has clearly helped many national regulators and utilities realise safety improvements of their NPPs, thus implementing the lessons learned from the Fukushima accident.

The JRC worked directly with Japanese research groups following the Fukushima disaster.

The JRC has a long-standing record of European and international engagement towards permanent improvement of nuclear safety, and has reinforced its contribution to the European post-Fukushima efforts with the set-up of a project on severe accident modelling and analyses for nuclear power plants. This project addresses on-site phenomena during the early and mid-term phase of an accident, and complements other on-going activities of the JRC in the field of emergency preparedness and radiation protection, such as environmental radiation monitoring and exchange of information on radioactive measures (including during emergencies). The scientific outcome of this project is expected to contribute to the technical foundations for future policy support to reviewing and implementing EU legislation on nuclear safety. It will also help to define research and development needs for the Euratom Horizon 2020 programme dedicated to promoting the highest safety standards in Europe. The JRC is also engaged in research on other aspects of nuclear energy, such as safety of fuels and fuel cycles, structural materials performance, component reliability and the safe management of radioactive waste and spent nuclear fuel.

As the maintenance of knowledge and competences are essential for the safe operation of nuclear installations, the JRC operates the European Human Resource Observatory for the Nuclear Energy Sector (EHRO-N), at the initiative of the European Nuclear Energy Forum (ENEF), with the task to monitor the supply of and demand for experts needed in the nuclear energy sector throughout the EU-27 for the years to come. The JRC has also established the Nuclear Safety and Security School (EN3S) that delivers highly specialised courses in various topics of nuclear technology.

Beyond EU borders, the JRC is engaged in promoting a high level of nuclear safety and radiation protection by supporting the projects implemented under two EU instruments: one is the Instrument for Nuclear Safety Cooperation (INSC) in countries outside the EU, the second is the Instrument for Pre-Accession Assistance (IPA), which addresses nuclear safety in countries on the way to EU membership. In addition, the JRC has established close cooperation with the relevant international organisations like the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency of the Organisation for Economic Cooperation and Development (OECD-NEA), and with other national organisations at a bilateral level.

The JRC contributes to studies on operational experience from which concrete lessons learned and recommendations from past experiences are derived on specific topics including events related to nuclear fuel and the construction of the nuclear power plants.

The JRC operates the European Human Resources Observatory for the Nuclear Energy Sector, collecting all relevant information as requested by its stakeholders, such as the mapping of the nuclear human resources demand and supply.

Work in progress

The JRC is strengthening the "operating experience feedback" in the EU by developing databases, organising training sessions and performing research into nuclear event evaluation techniques. It is delivering support to European post-Fukushima efforts needed to update the severe accident management strategies and practices. In addition, it addresses materials performance, component integrity, fuel and fuel cycle safety, radioactive waste management, and spent fuel management and it is enhancing radioactive environmental monitoring and exchange of radioactivity data measurements among Member States and other countries. The JRC also collaborates with the Sustainable Nuclear Energy Technology platform (SNETP) and delivers support to European networks. It is currently developing the human resources monitoring from nuclear engineering education monitoring towards knowledge/skills/competences monitoring, in line with the stakeholders' needs.

4.2 Nuclear energy technology

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission of 16 September 2011 - 1st situation report on education and training in the nuclear energy field in the European Union, COM(2011)563
- Communication from the Commission of 15 December 2011 - Energy Roadmap 2050, COM(2011)885
- Communication from the Commission of 22 November 2007 - A European strategic energy technology plan (SET Plan) - Towards a low carbon future, COM(2007)723
- Strategic Research and Innovation Agenda of the Sustainable Nuclear Energy Technology Platform
- Joint Programme on Nuclear Materials of the European Energy Research Alliance

The Sustainable Nuclear Energy Technology Platform (SNETP) gathers all major players in the nuclear field in Europe to promote research, development and demonstration (RD&D) of safe and competitive nuclear fission technologies. Its Strategic Research and Innovation Agenda is built on three pillars:

I > The Nuclear Generation II & III Association (NUGENIA) deals with plant life management of existing NPPs and the new build of Generation III Light Water Reactors.

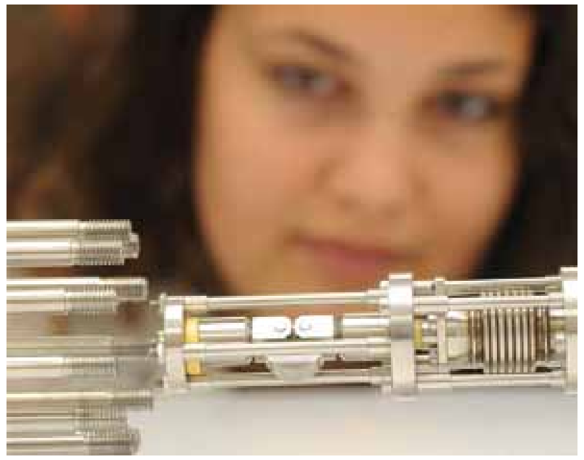
II > The European Sustainable Nuclear Industrial Initiative (ESNII) supports the development and demonstration of innovative fast neutron reactors with closed fuel cycles.

III > The Nuclear Cogeneration Industrial Initiative (NC2I) targets demonstration and deployment cogeneration of heat and electricity, using high temperature reactors or other suitable technologies.

The JRC supports these three SNETP pillars by participating in its organisation and by collaborating with other partners in related RD&D projects, including shared cost actions.

Service lives of up to 60 years seem feasible today for long-term operation of current nuclear reactors. The next generation of nuclear power plants envisages higher burn-up of the nuclear fuel, higher temperatures and new coolant environments. With its dedicated testing infrastructures, the JRC contributes to closing technology gaps through pre-normative RD&D into codes and standards needed for nuclear engineering. As materials are key enablers for safe nuclear technology the JRC supports nuclear safety and innovation by exploiting state-of-the-art research infrastructures for the performance and reliability characterisation of materials and components. This applies to reactors in operation where the ageing of materials has to be assessed, as well as to future reactors with new requirements for more advanced materials. The JRC's research and development activities comprise the assessment of structural materials with respect to their thermo-mechanical, corrosion and irradiation performance, taking into account high temperature coolant compatibility and long-term operation. Also the development of codes-of-practice and standards for advanced testing techniques, inspection procedures and data management tools are pursued in support of a safe and sustainable operation of nuclear installations in Europe.

In addition, the JRC looks into the wider role of nuclear energy in combating climate change by developing technical and economic assessments of specific reactor technologies.



Miniaturised device for rig stress corrosion cracking tests in Light Water Reactor environments.

The JRC has contributed to advancing a European Design Code for future nuclear facilities through a dedicated European Committee for Standardisation (CEN) workshop and a feasibility study on the needs for standardised rules for design and construction for future nuclear reactors.

Other important JRC highlights include the online materials database MatDB, which hosts for example the IAEA surveillance databases for pressure vessel steels, and the JRC's work to promote the standardisation for preserving and exchanging materials data.

Work in progress

Noting that public acceptance is fundamental for energy technologies and nuclear energy in particular, the JRC will develop its competence with regard to modern inclusive governance, based on early public information and participation, in support of energy policies.

4.3 Expectations of nuclear energy in a diversified energy mix

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission of 15 December 2011 - Energy Roadmap 2050, COM(2011)885
- Communication from the Commission of 22 November 2007 - A European strategic energy technology plan (SET Plan) - Towards a low carbon future, COM(2007)723
- Strategic Research and Innovation Agenda of the Sustainable Nuclear Energy Technology Platform

The political will to increase the fraction of variable renewable energy in future energy mixes is expressed in the Energy Roadmap 2050, where different scenarios towards the European decarbonisation targets were proposed. In these scenarios for 2050, renewable energy sources contribute with 40-60% to electricity generation and nuclear energy with up to 18%. Other organisations have also performed scenario studies, predicting the share of nuclear energy to remain stable by 2050, with around 28%, which means there is a significant need for a new build of nuclear power points (NPPs), due to the gradual retirement of currently operating ones.

Whatever the reality will be, the role of nuclear power will depend on the share of renewables in future energy systems, the expansion rate of electricity transmission grids and developments in energy storage capacity. Maintaining a reasonable level of nuclear energy reduces the urgency and systemic costs for grid development and energy storage.

Today, NPPs are mainly producing base load electricity, which is the minimum amount of power that a utility or distribution company must make available to its customers. Only in a few countries, such as France and the USA, NPPs perform load following, i.e. adapt their generation to fluctuating demands. In the future, even with improved grids and energy storage buffers, NPPs as well as gas and coal fired power plants will be required to enhance their load following capability, both from a technical and economic point of view. A future fleet of NPPs may therefore consist of base load generation plants, as well as more flexible plants. Nuclear cogeneration reactors shifting between process heat and electricity production to balance the grid are another option for load balancing, which allows the NPPs to operate at full power continuously, which is beneficial from a technical and economic point of view. Analytical work on this topic is on-going to understand how nuclear power integrates best into future energy systems and which new applications it can serve.

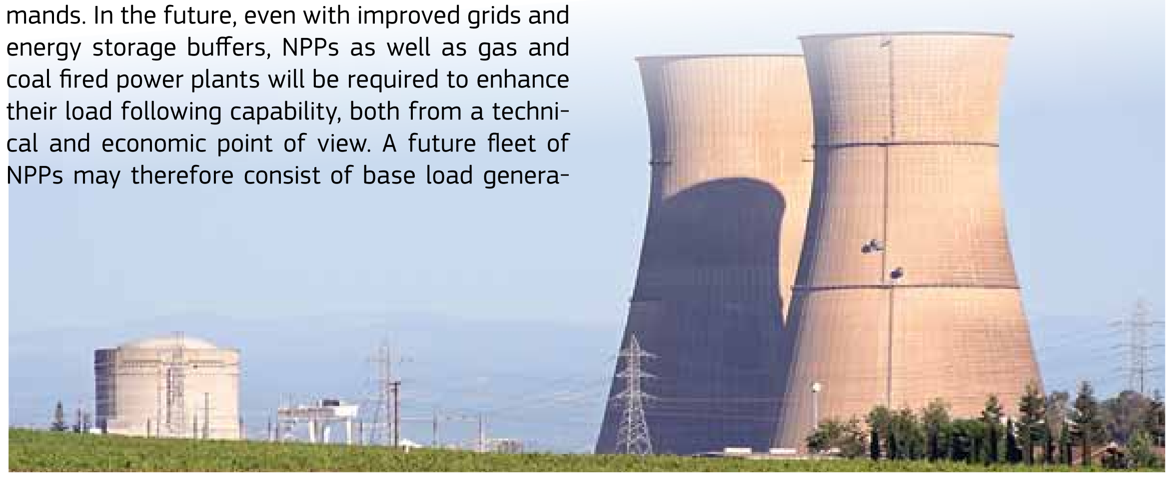
Reactor pool and vessel of the High Flux Reactor.

The JRC has carried out studies of the competitiveness of nuclear power and cogeneration with fossil fuels in the future energy system. It was concluded that nuclear power is competitive if capital costs are controlled, favourable financing obtained, externalities like CO_2 emissions are accounted for, and fossil fuel is not too expensive.

It also carried out studies on how nuclear energy can help integrate a larger share of renewables in order to reduce greenhouse gas emissions and to increase energy security. It was shown that nuclear energy can make important contributions to load balancing of the grid.

Work in progress

The JRC is planning more studies on system integration of nuclear energy with renewable energy sources and is conducting research on innovative Generation IV reactor systems, e.g in the area of materials, fuel and safety analysis.



5 Ensuring a safe hydrogen economy

Hydrogen is not a primary energy source like coal or gas, but is an energy carrier (similar to electricity) and can store and deliver energy in a variety of applications.

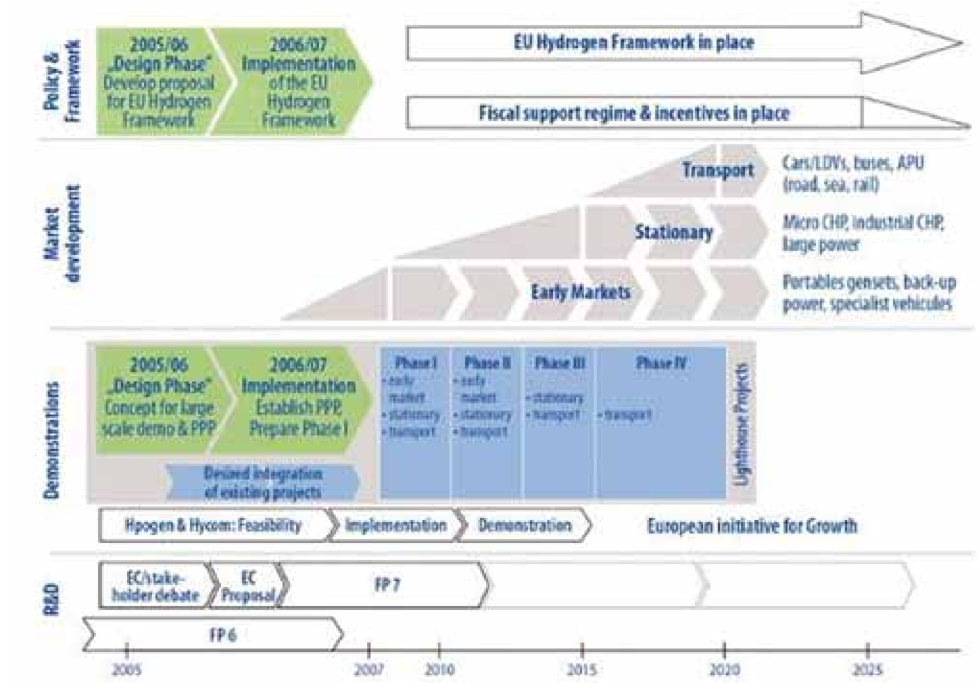
Hydrogen requires energy to be produced from a range of primary feedstocks. Once produced, it can be used as a fuel in combustion motors, or more efficiently in fuel cells – combined with oxygen – to generate clean electricity. At its point of use, it does not emit CO_2 or other pollutants. Because of these important environmental and energy security advantages, hydrogen is increasingly deployed in the stationary energy and transportation sectors. When renewable energy is used for hydrogen production or when CO_2 from fossil sources is captured, the complete chain from hydrogen production to end use is emission-free. In addition, as hydrogen is fully interchangeable with electricity, it can be used for energy storage, thus enabling large volumes of renewable energy to be fed into the electricity grid.

The huge environmental and energy security benefits that hydrogen and fuel cells can offer are explicitly recognised in a number of recent EU policy documents, such as the Low Carbon Roadmap, the Energy Roadmap and the Transport White Paper. Hydrogen and fuel cell technologies are therefore also covered in the EU's strategic technology plan for energy (SET-Plan) which includes the industry-led public-private partnership Fuel Cell and Hydrogen Joint Undertaking and Strategic Transport Technology plan (STT-plan). Reaping their benefits depends on increased market penetration, which requires further technology progress and innovation to reduce technology costs, and also on public acceptance. In this respect, it is paramount to ensure that the production, distribution, storage and use of hydrogen is at least as safe as that of conventional technologies and that the performance of hydrogen and fuel cell technologies in terms of efficiency, reliability, emissions, etc. can be objectively assessed and compared to that of incumbent technologies.

The JRC's research activities related to hydrogen mainly cover its storage and safety, and the assessment of fuel cells performance. The output of the JRC work, performed in cooperation with institutes in the EU, US, Japan, Korea is directly fed into European and international standardisation and regulatory bodies.

The JRC's activities in this area provide scientific support to the following policy initiatives:

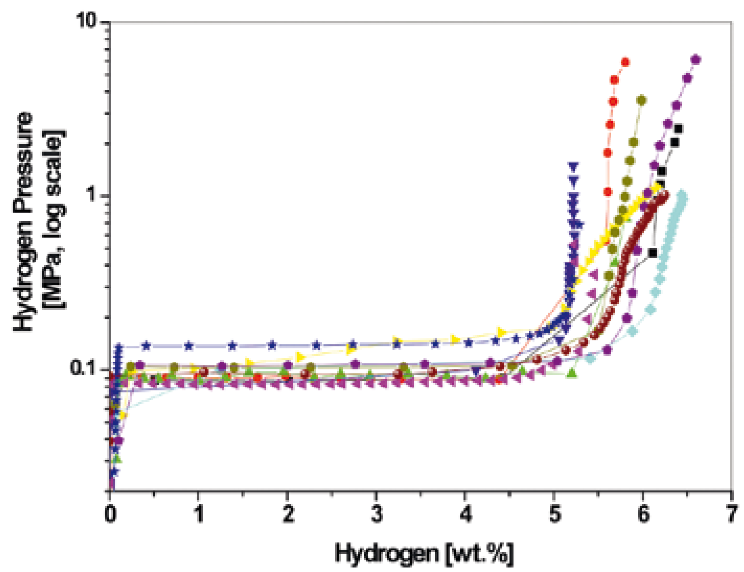
- Regulation No 406/2010 of 26 April implementing Regulation (EC) No 79/2009 of the European Parliament and the Council on type-approval of hydrogen-powered motor vehicles
- Regulation No 79/2009 of the European Parliament and the Council of 14 January 2009 on type-approval of hydrogen-powered motor vehicles, and amending Directive 2007/46/EC
- Directive 2009/142/EC of 30 November 2009 relating to appliances burning gaseous fuels
- White Paper on the Roadmap to a Single European Transport Area: Towards a competitive and resource efficient transport system, COM(2011)144
- Communication from the Commission of 15 December 2012 on the Energy Roadmap 2050, COM(2011)885
- Communication from the Commission of 8 March 2011, A Roadmap for moving to a competitive low carbon economy in 2025, COM(2011)112
- Communication from the Commission of 17 November 2010, Energy infrastructure priorities for 2020 and beyond - a blueprint for an integrated European energy network, COM(2010)677
- Communication from the Commission of 10 November 2010, Energy 2020 – A strategy for competitive, sustainable and secure energy, COM(2010)639
- Communication from the Commission of 7 October 2009 - Investing in the Development of Low Carbon Technologies (SET-Plan), COM(2009)519
- Communication from the Commission of 13 September 2012, Research and innovation for Europe's future mobility – developing a European transport-technology Strategy, COM(2012)501
- Communication from the Commission of 8 November 2011, CARS 2020: Action plan for a competitive and sustainable automotive industry in Europe, COM(2012)636



Schedule for deployment strategy on hydrogen and fuel cells.

5.1 Hydrogen safety

The JRC investigates and evaluates safety aspects related to the deployment of hydrogen technologies. For example, it assesses the consequences of hydrogen release for possible accident scenarios. Computational fluid dynamics modelling is used to simulate release, dispersion and combustion of hydrogen, and to compare these with releases of other gases (e.g. natural gas) to understand and minimise the risks involved with hydrogen use.



Comparison of hydrogen concentration measurements at 553 K in magnesium hydride performed in various laboratories over the world. The first international and formally organised inter-laboratory comparison ever for this specific storage technology.

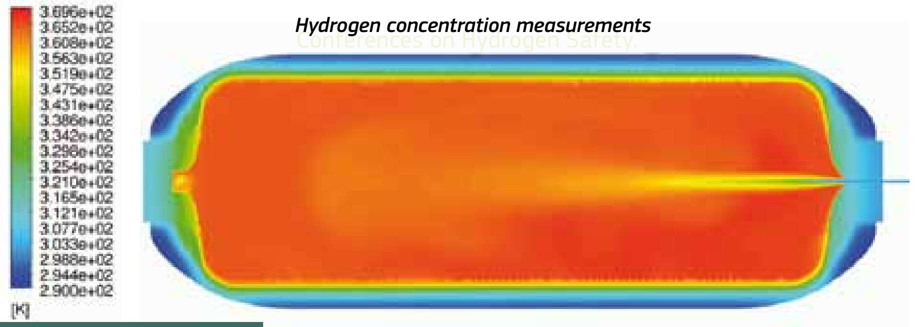
5.2 Hydrogen sensors

Since hydrogen has no colour, odour or taste and is therefore not detectable by human senses, special detection devices or sensors are needed to warn of its presence. The JRC operates a sensor testing facility to evaluate their performance under a wide range of environmental conditions.

5.3 Hydrogen storage

Another of the JRC's laboratories is responsible for testing and assessing hydrogen storage in solid-state materials. Research in this area covers establishing and improving methodologies to quantify hydrogen uptake and release, associated kinetics and energetic effects, as well as safety in handling these materials.

The use of hydrogen in transport, and in particular the challenge of storing hydrogen at high pressures to achieve sufficient driving range of passenger cars, is also tested at the JRC.



Temperature distribution inside a hydrogen vehicle tank during refilling.

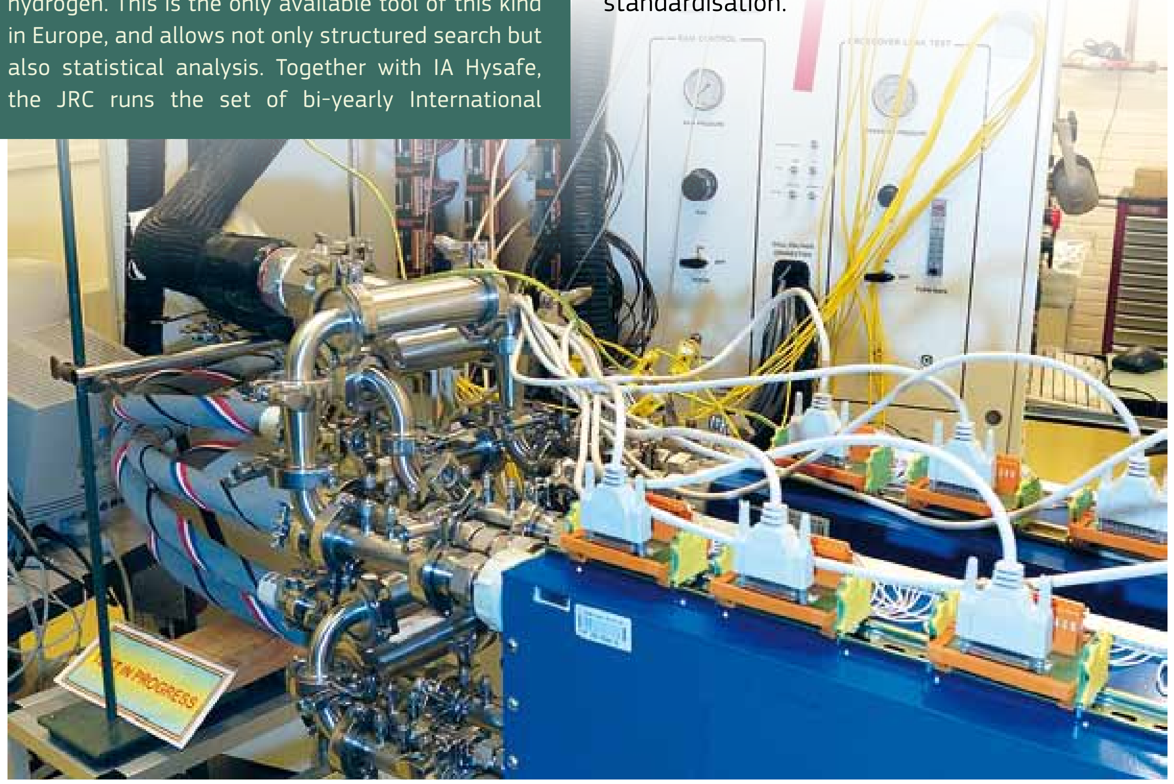
The JRC's hydrogen and fuel cell activities serve to establish harmonised methods in order to assess technology performance and safety. In this framework, the JRC has successfully organised, performed and evaluated the first world-wide interlaboratory exercises for assessing hydrogen sensors (2010), fuel cells (2009), hydrogen uptake in solid-state materials (2010), and fast-filling of tanks (2012). In a similar effort, the JRC has contributed to the design, execution and benchmarking of international modelling exercises on hydrogen safety. Results of this work are incorporated in new or improved standards and regulations, some of which are initiated and drafted by the JRC.

The JRC's expertise and impartiality is exploited in the work programme of the Fuel Cells and Hydrogen Joint Undertaking, an industry-led public-private partnership, where it is entrusted to act as a reference laboratory to assess scientific and technical progress.

For the International Association on Hydrogen Safety (IA Hysafe), the JRC runs and maintains the European Hydrogen Incidents and Accidents Database (HIAD). This database contains detailed and validated data on accidental events related to hydrogen. This is the only available tool of this kind in Europe, and allows not only structured search but also statistical analysis. Together with IA Hysafe, the JRC runs the set of bi-yearly International

Work in progress

The JRC will contribute to fostering innovation to achieve a wider deployment of hydrogen in transport and in stationary power applications. For this it will keep up its active involvement in pre-normative research in an international context, establishing and validating performance and safety assessment methods for hydrogen and fuel cell technologies. The JRC also serves as EU reference safety centre for identifying and modelling potential hydrogen accident scenarios, for carrying out safety and performance assessments of high-pressure gas storage tanks, for experimental evaluation of existing and future hydrogen sensor technologies, for measuring the hydrogen storage thermodynamic parameters in solid-state materials and systems, and for performance characterisation of different fuel cell types at cell, stack and system level. In addition, the JRC is carrying out comprehensive evaluations of hydrogen & fuel cell technology potential and advising on the prioritisation of research, particularly for European and international standardisation.



6 Assessing the role of energy technologies

The EU currently depends on – mostly imported – fossil fuels for 80% of its energy needs, which is problematic in relation to climate change as well as security of energy supply. There is thus an urgent need for energy technology innovation with high performing, innovative, low carbon and cost-effective technologies so that the energy system of today can transform in order to establish energy sustainability, competitiveness and security by 2020 and beyond.

6.1 An energy technology policy for Europe

Innovation is key for these technologies to reach adequate cost competitiveness and performance characteristics. A key step forward towards a European energy technology policy has been the establishment of the European Strategic Energy Technology Plan (SET-Plan), which seeks to bring high potential technologies closer to commercialisation through research and innovation. It aims to accelerate the development and consequently the deployment of selected cost-effective low carbon technologies. Through this plan, the EU aims to meet its ambitious 2020 targets (20% reduction in greenhouse gas emissions, raising renewable energy consumption to 20%, 20% improvement of energy efficiency) with an eventual aim to reduce emissions by 80-95% by 2050.

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission of 6 December 2012 – Renewable Energy: a major player in the European energy market, COM(2012)271
- Communication from the Commission of 15 December 2011 – Energy Roadmap 2050, COM(2011)855
- Communication from the Commission of 30 November 2011 – Horizon 2020 – The Framework programme for research and innovation, COM(2011)808
- Communication from the Commission of 3 March 2010: Europe 2020 - A strategy for smart, sustainable and inclusive growth, COM(2010)2020
- Communication from the Commission of 7 October 2009 - Investing in the Development of Low Carbon Technologies (SET-Plan), COM(2009)519
- Communication from the Commission of 4 November 2008 – The raw materials initiative – meeting our critical needs for growth and jobs in Europe, COM(2008)699
- Communication from the Commission of 22 November 2007 - A European Strategic Energy Technology Plan (SET-Plan) – Towards a Low Carbon Future, COM(2007)723
- Communication from the Commission of 10 January 2007 - Towards a European Strategic Energy Technology Plan, COM(2006)847
- European Innovation Partnership on Raw Materials

6.2 The Strategic Energy Technologies Information System (SETIS)

The SET-Plan comprises measures related to planning, implementation, human and financial resources and international cooperation in the field of research, development and demonstration (RD&D) of energy technologies. In this context, timely, reliable and independent information to underpin decision-making is paramount. This is the objective of the Commission's Strategic Energy Technologies Information System (SETIS) that is led and coordinated by the JRC.

Understanding the prospects of low carbon technologies, the economics and the timing of their contribution to Europe's policy goals are critical issues to be addressed in order to be able to support policy actions to foster technology innovation. Techno-economic assessments and modelling activities are essential for such analyses.

SETIS is led and managed by the JRC, which works in close collaboration with the Member States, European Industrial Initiatives (EIIs), the research community (through the European Energy Research Alliance – EERA) assisting SET-Plan governance by bringing together all the key players and supporting them in their decision making. SETIS provides up-to-date, validated and independent information on energy technologies and technology innovation. It addresses the complete portfolio of energy technologies, paying particular attention to the technologies under the SET-Plan, namely: wind energy, solar energy (photovoltaic and concentrated solar power), electricity networks, bioenergy, nuclear fission and carbon capture and storage.

SETIS provides information on strategic low carbon energy technologies.

6.2.1 SETIS outcomes

SETIS publishes a number of regularly updated key references on the state of low carbon technology, research and innovation in Europe. Its main publications are technology and capacities maps, and technology roadmaps.

The Technology Maps describe the latest developments for energy technologies in Europe and set forth the status of the corresponding low carbon technologies and their potential, the barriers to large-scale deployment, the needs of the industrial sector in order to reach the technology goals and the synergies with other sectors, as well as the on-going and planned R&D and demonstration efforts in Europe. This information makes them a valuable asset for policy makers to support their decision making. The Capacities Maps estimate both public and private R&D investments in the SET-Plan portfolio of technologies. This information serves as a benchmark for the current R&D spending and is a basis to assess the future research investment needs for meeting the SET-Plan goals. The Technology Roadmaps provide a master plan of the research, development and demonstration efforts needed in the EU over the next 10 years. They form the basis for the detailed 2-3 year long implementation plans of the European Industrial Initiatives.

The JRC has also contributed to the development of a Materials Roadmap highlighting the need for key materials research and innovation activities, throughout the supply chain, to advance energy technologies and to enable their deployment. It is designed to serve as a pragmatic guide for research and innovation programmes on materials for energy technologies, both at EU and Member State level.

6.2.2 Monitoring and review of SET-Plan actions

SETIS monitors the progress of the SET-Plan implementation, through an agreed monitoring and review framework based on key performance indicators. Through this, SETIS is able to define new priorities, review and identify synergies, set objectives and identify corrective policy measures if needed.

In addition, with the assistance of a range of models and other tools, SETIS assesses the impact of the SET-Plan implementation on the energy and climate objectives and on its effectiveness in reducing the costs for meeting these objectives.

SETIS disseminates information and output online, featuring the implementation plans of the European Industrial Initiatives, technology information sheets, articles, announcements and interviews with key sector players. SETIS has also developed a number of infographics and tools that are part of its website, such as the bubble graph which displays the maturity, maximum energy potential, and challenge for implementation of selected low carbon technologies, see figure 1.

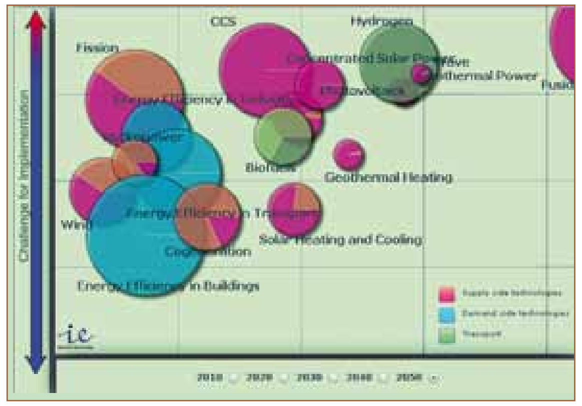


Figure 1: The Bubble graph illustrating the maturity, energy potential, and challenge for implementation.

The JRC, together with members of the European Industrial Initiatives (EIIs), has developed key performance indicators (KPIs) to monitor the European Industrial Initiatives (EIIs).

KPIs are considered programme milestones for each key action within the work programme of a European Industrial Initiative. KPIs are therefore programme specific, although based on a common approach. Common indicators for each Initiative are the cost/capital proportions, the operation & maintenance costs and the production costs of the related energy.

6.3 Other scientific research in support of the European energy and climate policy

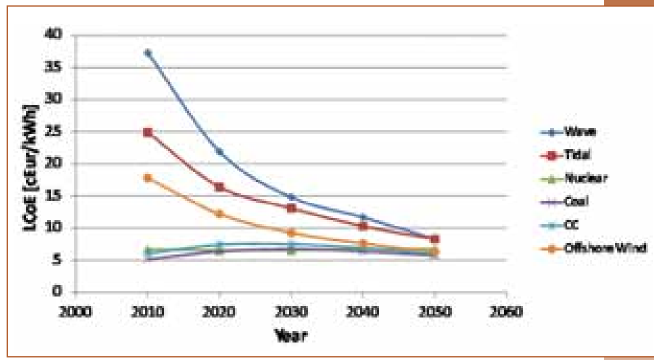
In addition to the regular before-mentioned reports, several scientific results related to and supporting the European energy and climate policy are published in reference reports and journal papers. Research includes critical materials in low carbon energy technologies, marine energy, wind energy, electricity storage and pumped hydropower.

6.3.1 Critical materials in low carbon energy technologies

In recent years there has been worrying rapid growth in the demand for raw materials. The EU is tackling this problem through the Raw Materials Initiative and the European Innovation Partnership on Raw Materials. In support of these policy initiatives, the JRC conducted two studies to assess whether there could be any potential bottlenecks to the large-scale deployment of low carbon energy technologies due to the shortage of certain metals. The first study focused especially on the demand of metals for the six low carbon energy technologies of the SET-Plan, i.e. nuclear, solar, wind, bioenergy, carbon capture and storage (CCS) and the electricity grid. A criticality screening was performed using market and geopolitical factors, which showed that five metals were at high risk of depletion, with particular effect on the wind and solar sectors. The second, follow-up study looked at other low carbon technologies that are competing for the same materials, such as fuel cells and hydrogen, electricity storage, lighting, road transport and others. This study has shown that, under similar criticality criteria, eight elements highly risk becoming depleted.

6.3.2 Marine energy

Marine energy can play an important role in Europe's future electricity supply system as the resources are vast and the carbon footprint of marine technologies is low. Moreover, it will contribute to economic growth of coastal regions with decreasing employment rates. It also represents a good opportunity for the European industry to develop and export low carbon technologies. Together with other major European stakeholders, the JRC carries out research and provides policy support for the development of marine energy technologies, within the SETIS framework. This includes assessments of the European wave and tidal energy potential, including quantification of resources and localisation of favourable application sites. Furthermore, the JRC performs techno-economic assessments with the main focus on identifying technology gaps and barriers with the purpose of accelerating cost reductions of wave and tidal power generation and bringing them to competitiveness. These analyses are essential for arriving at solid policy recommendations for a marine energy market deployment strategy.



Expected evolution of the energy costs for different sources until 2050. LCoE = levelised cost of energy (the price at which electricity must be generated from a specific source to break even over the lifetime of the project).

6.3.3 Techno-economic assessment of wind energy

The JRC initiated an annual review of the technological, market and economic aspects of wind technology. The first issue of the corresponding report builds on, and extends, JRC research contributing to EU policy initiatives such as the Technology Map, the annual Renewable Energy Snapshots, scientific assessments of materials use in wind power, modelling the cost of wind energy, and others.

Figure 2, based on data from Eurostat, shows that the whole wind farm park in Europe has had a clear increasing capacity over the last ten years. This is mostly the result of technological innovations, such as turbines with larger rotor diameters being increasingly installed in low wind areas.

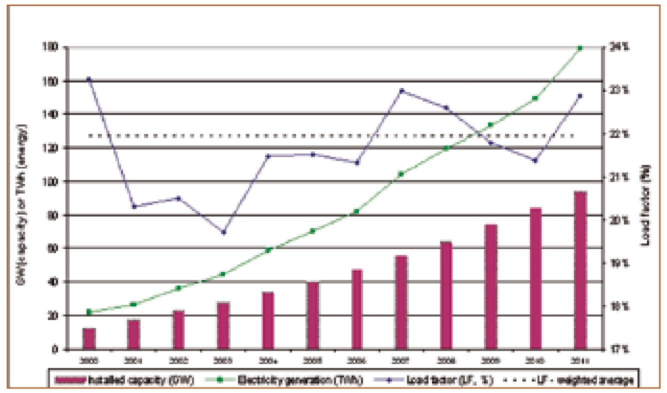


Figure 2: Wind energy generation, installed capacity and load factors. The whole wind farm park in Europe has had a clear increasing capacity over the last ten years.

6.3.4 Electricity storage

The transition from a centralised to a de-centralised energy system through the liberalisation of power markets, together with the further uptake of renewable energy technologies, has deep repercussions on the European energy sector. In this changing context electricity storage technologies (EST) play a central role.

Among EST, pumped hydro storage (PHS) has been used as a major provider of electricity from several sources for nearly a century. In the last decades the increased level of variable electricity generation has renewed the interest in the development of electricity storage as a key option for mitigating the effects of energy resources variability. New investments in pilot projects for storage technologies at the early stage of development have been undertaken. However, their market viability is a challenge.

The SET-plan has dedicated increasing attention to EST to gain a more thorough knowledge of the specific benefits of power storage applications. Several studies have been conducted to assess the market and regulatory drivers which would enhance their development and mass deployment. Investments in current available storage technologies are system dependent, and are mainly driven by the generation technology mix, grid interconnections, market pricing and regulation.

Figure 3 categorises existing power storage technologies according to their levels of maturity of development and investment costs across different power sectors: generation, transmission and distribution and end user. This matrix contains a first important guideline for decision making in investments in EST and provides a basic overview of the trends and development of current technologies.

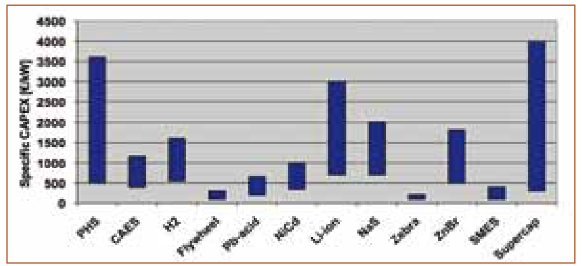


Figure 3: Existing power storage technologies according to their levels of maturity of development, investment costs across different power sectors: generation, transmission and distribution, and end user.

6.3.5 Assessment of the potential for energy storage – pumped hydropower

As the Commission aims to boost electricity storage, the JRC developed a methodology and model to assess the potential for new pumped hydropower storage.
Figure 4 shows the potential for new pumped hydropower energy storage capacity for different countries under certain assumptions, the most important of which is that the potential is based on one existing reservoir and that there is a 20 km radius.

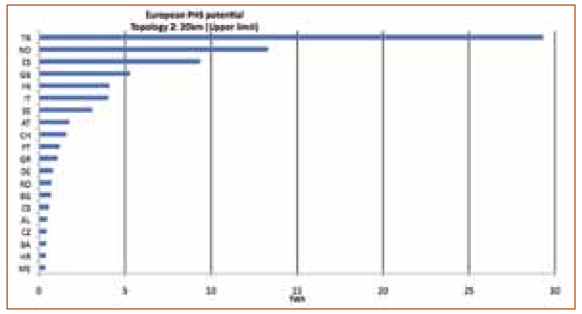


Figure 4: The potential for new pumped hydropower energy storage capacity for different countries under certain assumptions.

Work in progress

Some of the future work priorities are reviewing and monitoring the progress of the European Industrial Initiatives; and discussing methodological approaches with experts to quantify the impact of increasing research, development and demonstration (RD&D) on technology costs and performance, and the implementation of such approaches in the JRC model suite. The socio-economic value of wind energy will also be studied in the near future.

7 Energy Technology Innovation

The JRC is working on several innovative technologies, such as High-Voltage Direct Current technology, modelling the technology innovation, fuel cells and a new generation of nuclear energy systems.

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Directive 2003/54/EC of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC
- Communication from the Commission of 12 April 2011 - Smart Grids: from innovation to deployment, COM (2011)202
- Communication from the Commission of 3 March 2010 - Europe 2020: A strategy for smart, sustainable and inclusive growth, COM(2010)2020

7.1 High-Voltage Direct Current (HVDC) technology

Energy infrastructure – electricity grids in particular – are key to all our climate and energy goals. To save 20% of our estimated energy consumption by 2020 via technology, we need smart meters and smart grids. These new technologies not only allow consumers to be more involved in their power consumption and energy habits, but also permit a higher penetration of renewable energy sources, including from neighbouring countries. Good interconnections between Member States are thus needed, allowing companies to offer their energy to all. In this context, the JRC is collaborating with research and industrial partners to evaluate innovative transmission solutions, such as High-Voltage Direct Current (HVDC) technology.

HVDC technology converts alternative current (AC) voltage of the conventional power grid into DC voltage, and is converted back into AC voltage upon arrival. In contrast with conventional alternating current transmission systems, HVDC technology offers lower capital costs and lower losses for transmitting large amounts of power point-to-point over long distances (including undersea cables). In that sense, HVDC technology can be a cost efficient solution of stabilisation between the different AC networks by allowing them to draw energy from each other in emergency cases and failures.

Further development of the power markets and systems should therefore be considered if the EU wants to meet its ambitious energy objectives. One of the crucial requirements is indeed the expansion and diversification of transmission links inside the EU's networks and the neighbouring regions. In particular, solar energy in the Middle East and North Africa, and North Sea wind energy have been drawing increasing interest due to their sustainable energy potential. Renewable energy sources are intended to play a capital role, with a high share in gross final electricity consumption to provide sustainable, competitive and secure electricity for Europe.

It is in this particular framework that the JRC also carries out pre-normative research on High-Voltage Direct Current (HVDC) technology. It predominantly assesses the impact on the pan-European power system of multi-terminal Direct Current topologies (different ways of connecting points), allowing an efficient long distance energy transfer with a high penetration of renewable energies.

The output of this research is intended to support the related ongoing EU smart grid standardisation process.

The JRC has developed an experimental interconnection based on a real-time digital simulator with the voltage source converter based multi-terminal DC grid for testing and validating different models and control strategies.

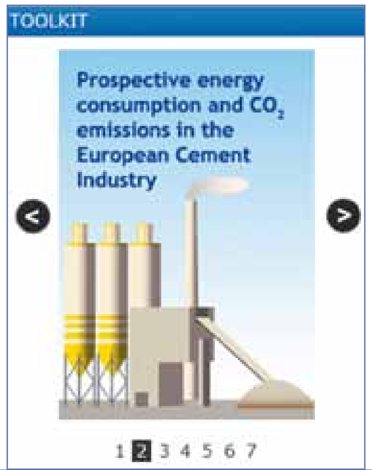
In addition, the JRC assesses multi-terminal direct current grids to integrate large scale offshore wind power in the North Sea (in cooperation with the energy research centre of the Netherlands (ECN) and the Technische Universiteit Delft).

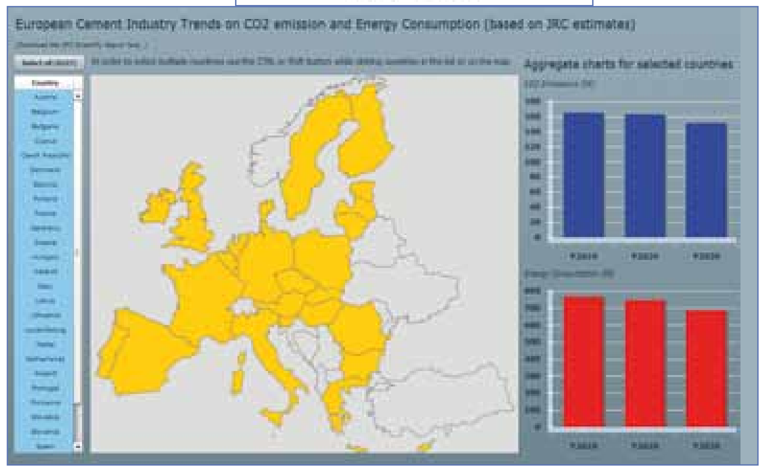
The JRC set up and is testing a stand-alone configuration with three small-scale voltage source converters.

Work in progress

The JRC will gather and process data of the Mediterranean region power system and update its Europe-wide model and carry out experiments for super grids. It will contribute to the North Sea Transnational Grid Project and establish an active partnership with the Mediterranean electricity systems actors via the European Commission platform of Mediterranean Transmission System Operators (Med-TSO).

SETIS-tool showing the European cement industry trends and CO_2 emissions and energy consumption





The JRC is assessing the impact of the market roll-out of best available technologies (BAT) and innovative technologies on the reduction of greenhouse gas emissions and energy consumption in the energy-intensive industry. This work, in progress, is achieved through the development of suitable analytical models and scenarios for the evolution of various industrial sectors.

7.2 Modelling technology innovation in the energy system

The JRC has developed and uses a number of modelling tools to analyse the drivers and the role of energy technology innovation in the energy system. These tools are important as they can guide policies and investments in energy technology related research, development and demonstration activities.

The JRC covers a wide range of modelling techniques in order to assess the overall prospects of technology innovation in the current and future energy landscape.

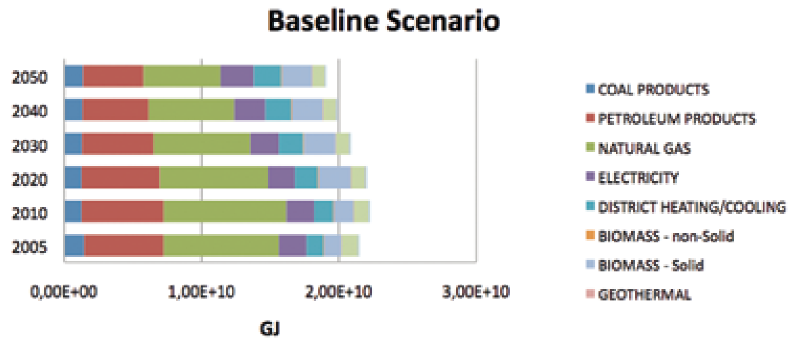
The need for techno-economic models ranges from tools that look into technology penetration in the energy sector down to techno-economic engineering models capable of simulating technology developments and their impact on operational and economic performance. The JRC uses the different tools and models in a flexible reconfigurable way so that the most appropriate tools can be used for catering the various policy needs.

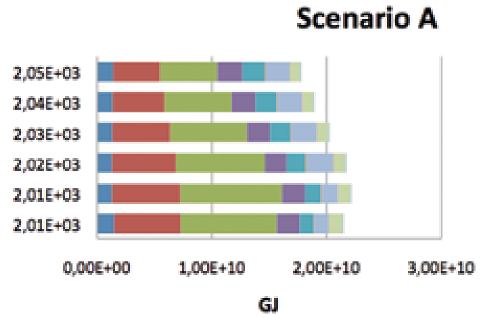
Detailed models on a technology level help to describe the techno-economic improvement potentials, which are then used to analyse potential technology transition scenarios and their impacts in sub-sectors such as the energy intensive industry.

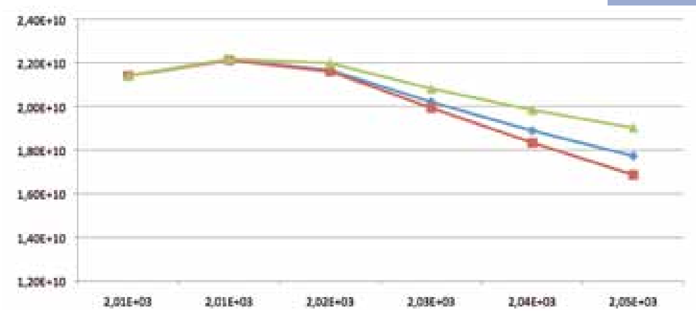
Broader energy system or energy market models are then used to analyse and quantify the role of each sub-sector and its impacts on a system level. The JRC maintains and uses technology rich energy system models, broken down at EU Member State level that can study in detail the uptake of future technology options under different scenario assumptions. A typical question from policy makers, especially in times of tighter public budgets is, to what extent public funding can boost innovation and if this leverage effect can be quantified.

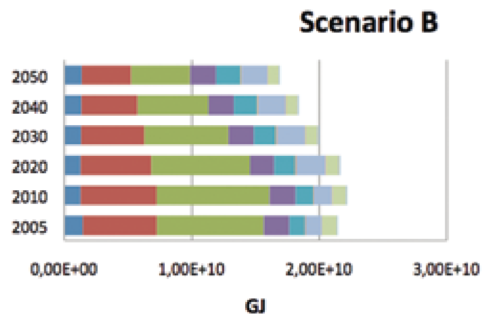
The JRC constantly interacts with the scientific community in order to continuously improve its modelling capabilities. This is especially important as there is no "one model fits all" solution.
For the ATEST project (Analysing Transition Planning and Systemic Energy Planning Tools for the implementation of the Energy Technology Information System), the JRC partnered up with prestigious European research organisations and analysed transition planning and systemic energy planning tools to aid the implementation of the SET-Plan.

Evolution up to 2050 of the final energy demand for heat in the EU-27









Baseline scenario (no changes), scenario A (50% more Best Available Technologies or BATs in the heat sector versus baseline) and scenario B (100% more BATs in the heat sector versus baseline).

Through a model based approach, in 2010 the JRC quantified the impact of the Strategic Energy Technology Plan on the European Power Sector.
In this study the cost evolution of the specific technologies were modelled as a function of a combination of cumulative production (learning-by-doing) and knowledge stock (learning-by-researching). In the study, the JRC calculated that the economic rate of return of the additional SET-Plan investments (in research, development & demonstration in the EU) would be around 15% between 2010 and 2030.

Work in progress

Some of the future work priorities are intensifying the analytical modelling activities in the JRC; providing key input to models considering the evolution of energy technologies, based on the work of SETIS (the Strategic Energy Technology Information System); and expanding the Energy Technology Reference Indicator project to support the modelling activities.

7.3 Fuel cell technology innovation

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission of 22 November 2007 - A European Strategic Energy Technology Plan (SET-Plan) – Towards a Low Carbon Future, COM(2007)723
- Communication from the Commission of 13 September 2012 – Research and innovation for Europe's future mobility – Developing a European transport-technology strategy (Strategic Transport Technology Plan – STT-Plan), COM(2012)501
- Communication from the Commission of 6 October 2010 on the Innovation Union Flagship of the EU 2020 Strategy for a resource efficient Europe, COM(2010)546

Fuel cells are the most efficient energy converters presently known. They produce electricity, heat and pure water vapour as an exhaust, which makes them very environmentally friendly. For their operation they do not rely on mechanically moving parts, which makes them less susceptible to friction, reduces losses, increases reliability and makes them very quiet. There are different types of fuel cells which can be fed by different fuels (including hydrogen) and have different operating temperatures and performances. Unlike other power generation technologies, fuel cells do not pollute or consume water. Some fuel cell types even allow concentrating CO_2 from the fuel, which makes it possible to capture it without energy loss, whereas others can also produce hydrogen. Because of all these attractive characteristics, fuel cells are being increasingly used in stationary applications such as residential combined heat and power, production of premium power, uninterrupted power supplies, back-up systems, as well as for automotive transport.

Fuel cells are considered to have huge potential to contribute to the EU's energy, climate and transport policy goals, but have so far failed to establish themselves on the market. There are no emissions at the point of use and the primary energy needs are reduced because of the high conversion efficiency. However, at present, fuel cells are more expensive than competing technologies in energy and transport applications and, depending on the type of fuel cell, still need improvement in terms of durability or reduced sensitivity to impurities in the fuel. Only by continued technological improvement and by increased market penetration can they fully contribute to the EU integrated climate and energy policy goals. Both the US and Japan, but also upcoming economies such as China and Korea, have major national programmes supporting hydrogen and fuel cells politically and financially. The EU should ensure that it does not lose its competitive position in these new "green" technologies and hence needs investment in innovation of these, to a certain extent disruptive, and hence less publically accepted and appreciated, technologies.

For fuel cells to develop their full potential in the EU, an appropriate legislative and regulatory framework is needed, creating a level playing-field with competing technologies. The JRC addresses this gap and contributes to innovation in this area by developing and validating test methods representative of actual service which account for the specificities of the technologies and of their end use application.

The JRC executes pre-normative research that enables the development of scientifically sound, validated and fit-for-purpose European and international standards in fuel cells, which are a major enabler of global technology innovation.

The JRC operates a unique fuel cell testing facility which allows characterisation of fuel cell systems under closely controlled conditions of fuel and air purity, temperature (-40 to +60°C) and relative humidity (0-95%). Tests can also be performed under vibration using a six degrees-of-motion shaking table housed in the environmental chamber. This combination enables the identification of the parameters and factors that have to be included in the test methods and procedures in order for the test results to reflect the conditions that fuel cells are expected to meet in real life. Test methodologies cover performance in terms of efficiency, emissions, reliability, durability and degradation and fuel purity requirements. The results of this pre-normative research are validated through European and international inter-laboratory studies and directly fed into European and international standardisation test methodologies and procedures. Furthermore, they allow comparison and benchmarking of fuel cell performance with that of conventional, competing technologies, both in the energy and transport sectors.

Work in progress

The JRC will strengthen its pre-normative research efforts in energy and transport technologies, including fuel cells. The Innovation Union initiative explicitly acknowledges the importance of standards as enablers of innovation in areas which are critical for EU policy goals, such as energy and transport. Regulation (EU)1025/2012 on European standardisation established that the JRC shall provide the science-base for European standardisation, in particular for harmonised standards that are referred to in European legislation.

7.4 Towards a New Generation of Nuclear Energy Systems

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission of 22 November 2007 - A European strategic energy technology plan (SET Plan) - Towards a low carbon future, COM(2007)723
- The Joint Programme on Nuclear Materials of the European Energy Research Alliance
- The Generation IV International Forum (GIF)

After the development of the early water- and gas-cooled reactors, the political priority driving nuclear innovation was mainly security of energy supply (e.g. anticipated growth of electricity consumption, limited access to fossil fuels and uranium). After the oil shocks in the 1970s, large new-build programmes in several countries were considered the key to more energy independence. The resulting substantive growth in uranium consumption compared to a then relatively limited known uranium resource base spurred the development of fast breeder reactors until the Chernobyl accident, financial considerations and relatively cheap oil halted these projects in Europe in the late 1980s.

More recently, since 2001, the Generation IV International Forum (GIF) reunites the major global players in nuclear energy. Since 2003, Euratom is a GIF member, with the JRC as the implementing agent. GIF had defined the following criteria for successful innovation:

- sustainability (resources, waste),
- competitiveness,
- safety and reliability,
- non-proliferation and physical protection.

GIF screened more than one-hundred reactor concepts for their potential to meet these criteria, and six of them were selected for further internationally coordinated research and development (R&D). Since then, the JRC along with Euratom project partners is contributing to related R&D on several of these reactor concepts, in accordance with the Sustainable Nuclear Energy Technology Platform (SNETP) strategy. The JRC also facilitates the development and performance of GIF R&D projects and disseminates their results to Euratom stakeholders.

Based on scientific results, the JRC fuels a strategic debate about nuclear R&D both at European and international level. It continues to work with major European stakeholders in SNETP to define and implement R&D priorities and strategies, and agrees with GIF on common coordinated R&D programmes.

In doing so and based on the lessons learned from the Fukushima accident, safety more than long-term fuel sustainability, has become the JRC's main driver for nuclear innovation. With this perspective and the already available R&D results in mind, and using updated and refined selection criteria, innovative reactor concepts for future R&D have to be reviewed. In addition, societal and economic aspects are to be addressed to understand and deal with the current obstacles for the development of innovative nuclear power. In this manner, the JRC will be in a better position to appreciate the possible future role of nuclear energy in Europe and to help adjust EU energy policies accordingly.

The JRC assesses the safety and feasibility of innovative nuclear reactors through its own work programme and participation in European projects. The topics comprise: fuel fabrication, fuel irradiation and safety testing, resistance of new materials against high temperatures and corrosion, pre-normative material tests for standardisation, safety and security analyses, development and testing of instrumentation, system integration, economic analyses etc.

Work in progress

The JRC is performing further safety analyses, for instance in the area of severe accident analysis in innovative nuclear systems, to clarify safety performance, and is also testing fuel and materials required to reach best safety performance. In addition, the JRC has started system studies to analyse and improve the compatibility of nuclear energy within a diversified energy mix, in particular, with renewable energy sources.

Further reading

Renewable energy

Renewable Energy Assessment

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Useful tools

The JRC has developed numerous scientific tools to study different energy-related topics. Most of them are available to the general public.

Here you can find an overview of the JRC's energy-related research tools:

Renewable energy assessment

- Photovoltaic Geographical Information System: http://re.jrc.ec.europa.eu/pvgis/
- Sustainability of Bioenergy website: http://re.jrc.ec.europa.eu/biof/
- Scientific and Technical Reference on Renewable Energy and End-Use Energy Efficiency: http://iet.jrc.ec.europa.eu/remea/
- Maps already produced: renewable energy resource map for Africa, solar radiation map for Africa, wind energy density map for Africa, biomass density map for Africa, mini hydro area suitability and hydro capacity map for Africa. http://iet.jrc.ec.europa.eu/remea/renewable-energies-africa-current-knowledge

Photovoltaics

- The JRC's Photovoltaic Geographical Information System (PVGIS): http://re.jrc.ec.europa.eu/pvgis
- European Solar Test Installation: http://re.jrc.ec.europa.eu/esti
- The JRC's Photovoltaic Power Calculator: http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php

Biofuel and bioenergy

- Biofuels coordinating action: http://iet.jrc.ec.europa.eu/bf-ca/
- Biomap: http://setis.ec.europa.eu/BIOMAP/#31016
- JRC-EUCAR-CONCAWE (JEC): http://iet.jrc.ec.europa.eu/about-jec/
- Alternative Fuels Action: http://iet.jrc.ec.europa.eu/alternative-fuels-alfa

Energy efficiency: doing more with less

- Scientific and Technical Reference on Renewable Energy and End-Use Energy Efficiency: http://iet.jrc.ec.europa.eu/remea/
- Up-to-date information on all Ecodesign measures: http://ec.europa.eu/enterprise/ecodesign
- ICT codes of conduct: http://iet.jrc.ec.europa.eu/energyefficiency/energy-efficiency-activities/ict-codes-conduct
- EU GreenLight Programme: http://iet.jrc.ec.europa.eu/energyefficiency/greenlight
- EU GreenBuilding Programme: http://iet.jrc.ec.europa.eu/energyefficiency/greenbuilding-programme/about-greenbuilding-programme
- Guidebook: How to develop a Sustainable Energy Action Plan (SEAP) – Guidebook. 2010. Luxembourg: Publications Office of the European Union.
  http://www.eumayors.eu/IMG/pdf/seap_guidelines_en-2.pdf
  http://www.eumayors.eu/IMG/pdf/004_Part_II.pdf
  http://www.eumayors.eu/IMG/pdf/005_Part_III.pdf
  http://www.eumayors.eu/IMG/pdf/Addendum_1_to_the_SEAP_Guidebook_Joint_SEAP_option_2.pdf

Smart grids

- Inventory of smart grid projects in Europe: http://ses.jrc.ec.europa.eu/project-maps
- Smart Grid Projects in Europe (joint JRC-EURELECTRIC smart grid platform): http://www.smartgridsprojects.eu/map.html
- Smart Grid Interactive Tool: http://iet7-dev.jrc.nl/ses/node/40

Safe Operation of Nuclear Power Plants

- EU Clearinghouse: https://clearinghouse-oef.jrc.ec.europa.eu/clearinghouse/
- SARNET – Severe Accident Research NETwork of Excellence: Network of Excellence: http://www.sar-net.eu/
- SARNET STRESA (Storage of Thermal Reactor Safety Analysis Data): http://stresa.jrc.ec.europa.eu/sarnet
- EHRO-N (European Human Resources Observatory for the Nuclear Energy Sector): http://ehron.jrc.ec.europa.eu/
- Support to International Nuclear Safety Activities: http://nuclear.jrc.ec.europa.eu/tacis-insc/index.php
- Capture – Knowledge Consolidation, Preservation and Dissemination in the Nuclear Energy Sector: http://capture.jrc.ec.europa.eu/
- Odin – Online Data and Information Network for Energy: https://odin.jrc.ec.europa.eu/

Hydrogen

- HYSAST - Hydrogen Safety in Storage and Transport: http://iet.jrc.ec.europa.eu/hysast-hydrogen-safety-storage-and-transport

Assessing the role of energy technologies

- SETIS – Strategic Energy Technology Information System: http://setis.ec.europa.eu
- Electricity Production Map and Statistics: https://odin.jrc.ec.europa.eu/SETIS/Eurostat/Main.html
- Energy calculator: https://odin.jrc.ec.europa.eu/SETIS/SETIS1.html#
- Bubble graph: https://odin.jrc.ec.europa.eu/SETIS/BG/Bubblegraph.html
- European cement industry trends on CO_2 emission and energy consumption: https://odin.jrc.ec.europa.eu/SETIS/CementIndustryMap/MapCementIndustry.html

Energy Technology Innovation

- ATEST website (Analysing Transition Planning and Systemic Energy Planning Tools for the implementation of the Strategic Energy Technology Information System): www.atest-project.eu
- IET fuel cells website: http://iet.jrc.ec.europa.eu/fuel-cells/
- Sustainable Nuclear Energy Technology Platform: www.snetp.eu

Partners

European Energy Research Alliance (EERA), European Wind Initiative, Solar Europe Initiative – photovoltaic and concentrated solar power, the European Electricity Grid Initiative, The European CO_2 Capture, Transport and Storage Initiative, the Sustainable Nuclear Initiative, The European Industrial Bioenergy Initiative, Energy Efficiency – The Smart Cities Initiative, the Joint Technology Initiative, ITER, F4E – Fusion for Energy, European Community Steering Group for the SET-plan, R&D Framework Programme, Sustainable Nuclear Energy Technology Platform, European Technology Platform for Wind Energy, ETP for the Electricity Networks of the Future, European Biofuels Technology Platform, Zero Emission Fossil Fuel Power Plants (ZEP), Renewable Heating and Cooling (RHC), European Photovoltaic Technology Platform (EUPV), Smart Systems Integration (EPoSS), European Committee for Standardisation (CEN), European Committee for Electrotechnical Standardization (CENELEC), European Bank for Reconstruction and Development (EBRD), European Investment Bank (EIB), European Telecommunications Standards Institute (ETSI), International Energy Agency (IEA), Intergovernmental Panel on Climate Change (IPCC), Österreichisches Institut für Baubiologie und -ökologie (IBO), Energetski institut Hrvoje Požar, Centre for Renewable Energy Sources (Greece), End-use Efficiency Research Group (eERG) – Building Engineering Faculty - Politecnico di Milano, ADENE-Agência para a Energia, Universitat Rovira i Virgili National, Fastighetsägarna Sverige, more than 700 GreenLight partners, among which AB InBev, GlaxoSmithKline, Grohe, ING, Johnson & Johnson, RTL TVI. GreenBuilding Partners, among which Woolworth GmbH (DE), Sparkasse KölnBonn (DE), SIEMENS S.p.A. (IT), Provincia di Venezia (IT), Pfizer AB (SE), KPMG Flintholm (DK), more than 60 Code of Conduct partners, among which Dell Corporation data centre, Thomson Reuters data centre, VCD Infra Solutions data centre, US Department of Energy (DoE), EURELECTRIC, Smart Grid Task Force, Florence Regulatory Forum for Electricity, European Network of Transmission System Operators for Gas (ENTSO-G) and for Electricity (ENTSO-E), International Food and Policy Research Institute (IFPRI), CONCAWE, EUCAR, European Environment Agency, Organisation for Economic Cooperation and Development (OECD), International Electrotechnical Commission (IEC), Photovoltaic European Research Infrastructure Coordination Action, ACP-EU Energy Facility, ACP Observatory for Sustainable Development, ENEA – Ente per le Nuove Tecnologie, l Energia e l Ambiente, United Nations Environment Programme, Fuel Cells and Hydrogen Joint Undertaking (FCH-JU), International Organisation for Standardisation (ISO), United Nations Economic Commission for Europe (UN-ECE), International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), International Energy Agency – Hydrogen Implementing Agreement (IEA-HIA), Utrecht University, European Wind Energy Association, Argonne National Laboratories, Mediterranean Transmission System Operators Association (MED-TSO), North Sea Transnational Grid Project (NTSG), TU Delft, Energieonderzoekscentrum Nederland (ECN - Netherlands), KTH (Sweden), TERNA (Italian Transmission System Operator), European Community Steering Group for the SET-plan, Gas Coordination Group (GCG), Lithuanian Energy Institute (LEI), European Fuel Cell and Hydrogen Joint Undertaking, Korean institute for Science and Technology, International Centre for Hydrogen Energy Technologies (UNIDO-ICHET), Institut de Radioprotection et de Sûreté Nucléaire (IRSN), International Atomic Energy Agency (IAEA), OECD Nuclear Energy Agency (OECD – NEA), over 50 SARNET partners, among which Atomic Energy of Canada Limited (AECL, Canada), Lithuanian Energy Institute (LEI, Lithuania), VTT Technical Research Centre of Finland (VTT, Finland), European Nuclear Energy Forum (ENEF), European Nuclear Education Network (ENEN), Sustainable Nuclear Energy Technology Platform (SNE-TP), European Nuclear Society (ENS), Foratom, GenIV International Forum (GIF), the International Nuclear Research Initiative (I-NERI), Association Française de Normalisation (AFNOR), National Institute of Standards and Technology (NIST), Electricité de France (EdF), Société nationale d'études et de construction de moteurs d'aviation (Snecma), Prague University, Pisa University, Nuclear Research and consultancy Group (NRG), Sustainable Nuclear Energy Technology Platform (SNETP)

The JRC works in close contact with a vast array of institutions, research networks and science-led public and private partners and is continuously strengthening co-operations on global issues with international partners and organisations. In the area of energy, cooperation is developed across the Atlantic and worldwide, with close collaboration with universities, government institutes and departments for energy, energy utility companies and international research bodies and organisations. A representative sample of these partners can be found on this page.

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Abstract
This report aims to give a comprehensive overview of the work of the Joint Research Centre (JRC), the Commission's in-house science service, in relation to the global energy challenge. The description of the JRC's work in this area is divided into seven chapters. For each chapter, the detailed policy context is cited, showing clearly how and where the JRC provides its scientific and technical support to energy-related policies. Furthermore, an ample list of publications for further reading is proposed as well as useful scientific tools such as maps, energy calculators, specialised information systems and databases.

JRC Mission

As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

Working in close cooperation with policy Directorates-General, the JRC addresses key societal challenges while stimulating innovation through developing new methods, tools and standards, and sharing its know-how with the Member States, the scientific community and international partners.

Serving society
Stimulating innovation
Supporting legislation

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